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REVIEW OF ENGINEERING PROGRESS ABROAD

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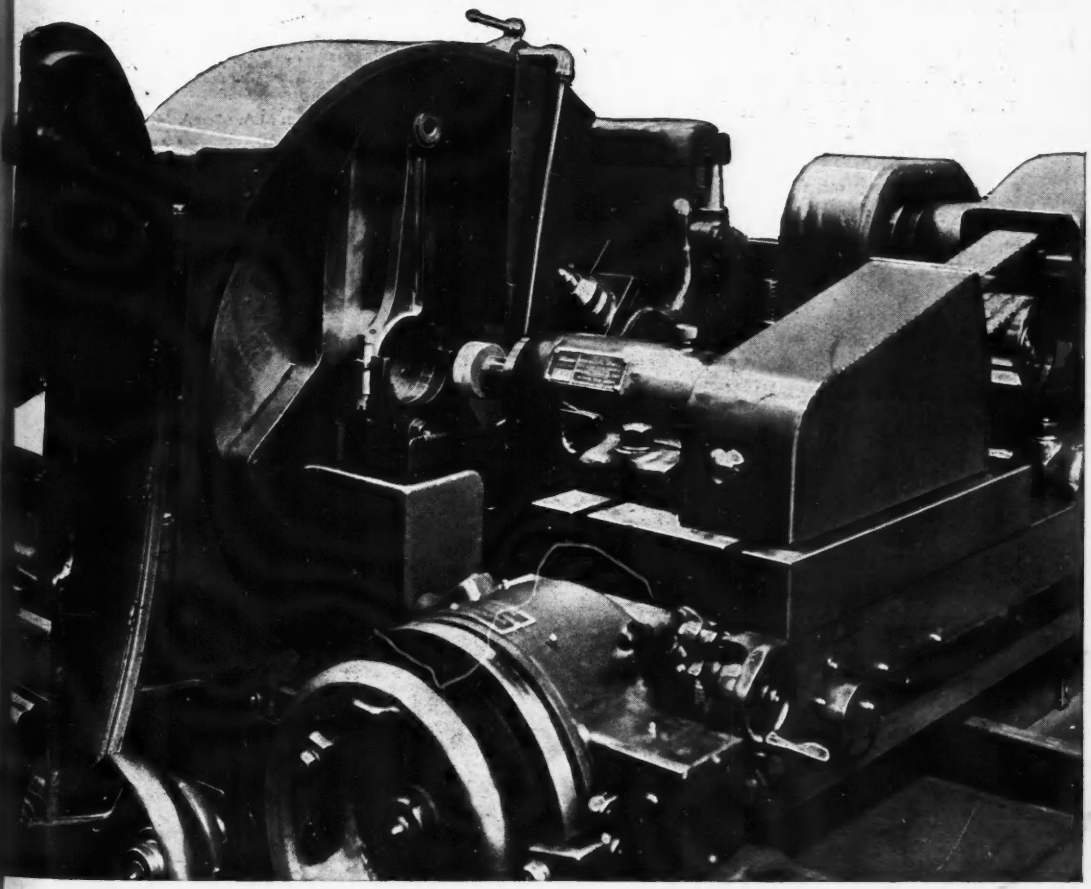

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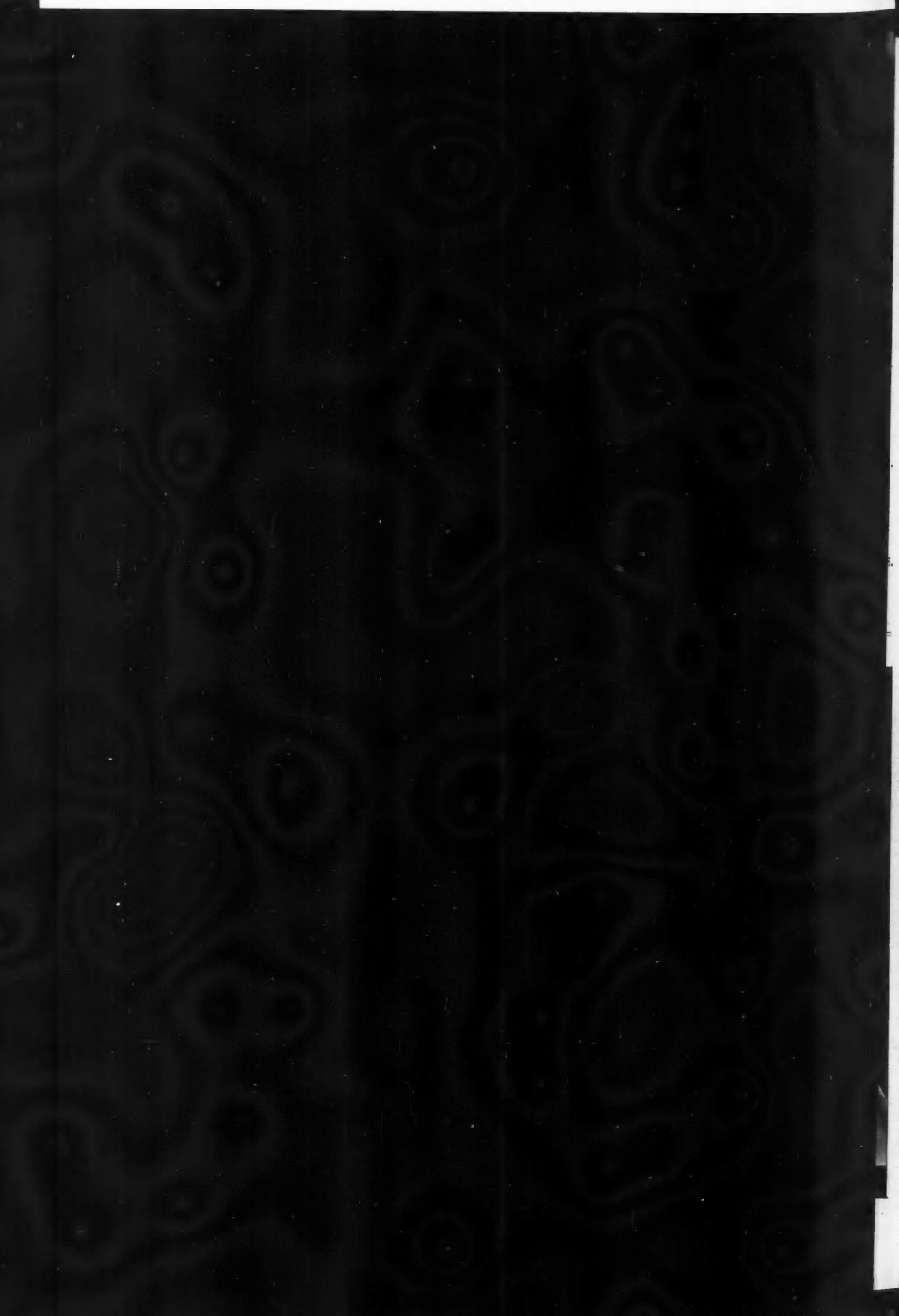

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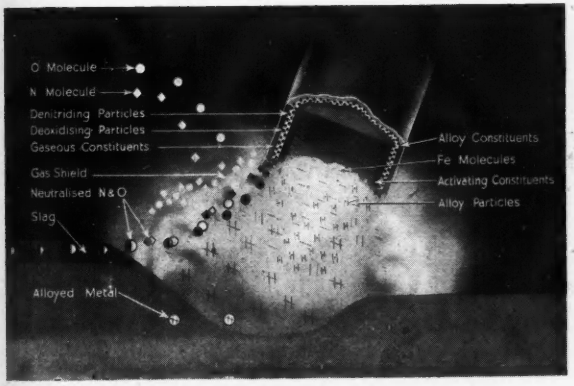

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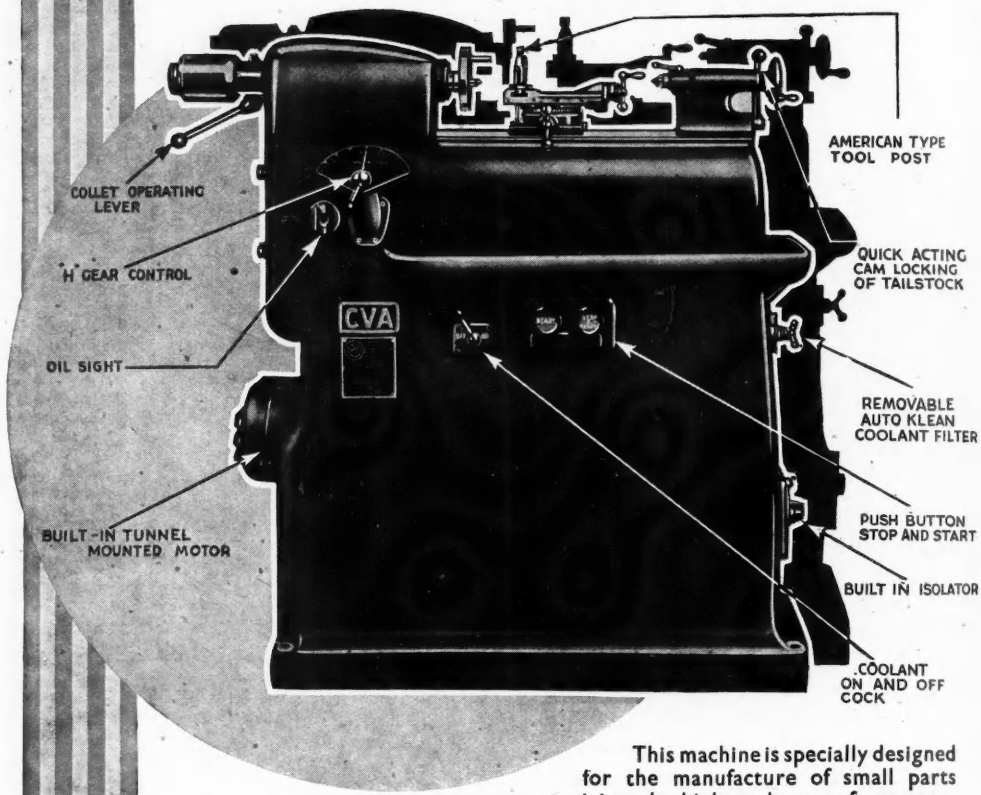

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PROBLEMS IN THE USE OF PLYWOOD IN AEROPLANE CONSTRUCTION

By ALEXANDER KLEMIN, Guggenheim Research Professor, School of Aeronautics, New York University.
(From *Mechanical Engineering*, Vol. 65, No. 2, February, 1943, pp. 105-109).

THE present paper takes for granted that aeroplane construction in plywood is fully accepted and recognized and undertakes the informal discussion of the difficulties and problems of this art. The study of these problems and their solution constitute the objectives of the A.S.M.E. Research Committee on Plywood in Aeroplane Construction, for which the author is acting as chairman. The work of the committee has been tentatively classified under the following headings :—

1. Aeroplane Veneer and Plywood Manufacture.
2. Selection, Inspection, Availability of Materials, and Specifications.
3. Adhesives and their Application.
4. Special Fabrication Processes.
5. Plywood Components of the Aeroplane, Fittings, and Connections.
6. Aeroplane Construction and Assembly in relation to Plywood.
7. Testing of Plywood and Plywood Parts.
8. Strength Properties of Plywood.
9. Structural Analysis.
10. Bibliography.

The present informal statement indicates the scope of the questions which the chairman is placing before the members of the committee.

Aeroplane Veneer and Plywood Manufacture.

In recent years the manufacture of veneer and plywood has advanced to such an extent that, in basic principle, methods of manufacture scarcely need improvement. The committee does not propose to study the matter of plywood manufacture, but merely wishes to draw attention to difficulties as the aeroplane constructor is apt to see them.

(*a*) Better selection and softening of logs seem to be necessary at times, because a $\frac{3}{16}$-in. ply may run off in thickness $\frac{1}{32}$- in.

(*b*) There may be variation in density in the veneer of a single sheet of plywood, and density variation implies strength variations.

(*c*) The thickness of a plywood panel may vary so much that in gluing together eight $\frac{1}{8}$-in. plies to make up a 1-in. panel, it may be necessary to mill down a face ply.

(*d*) The thickness of a panel and of its component veneers may remain uniform, but the grain may run wider apart at certain points with resultant loss of strength.

(*e*) Difficulties may arise in moisture control and in the selection of the primary wood.

Selection, Inspection, Availability of Materials, and Specifications.

With the aviation industry, wood has come to mean spruce and plywood, a panel with spruce core and beech faces. However, other woods for the cores of aeroplane plywood have to be sought such as poplar or fir. What sacrifice in strength properties do plywoods with such cores entail, and how should they be specified? These are questions to which definite answers are needed.

In the purchase of metals, steel or aluminium, composition and metallurgical processes are so rigidly specified that the purchaser can rely upon the corresponding physical properties. In the purchase of plywood, the lack of uniformity in the manufacturing processes may result in disappointing differences in strength, even though plywood has been brought on a standard Army or Navy specification. One practical problem lies, therefore, in the framing of even more rigid and inflexible specifications than those at present offered by the Government services. In such specifications, the question of allowable strength has to be defined much more precisely. Moreover, some consideration of tolerances should be in every specification.

Adhesives and their Application.

Modern synthetic-resin glues or adhesives are greatly superior to their predecessors of organic origin. If the manufacture of plywood from veneer is considered, synthetic resins of phenol formaldehyde in the hot-press process give satisfactory results and rapid production. But in aeroplane assembly, the use of cold-setting glues (casein or urea) is almost universal, and while processes at temperatures around 70° F. are satisfactory, they are slow. Moreover, if the cold-setting glue retains its adhesive properties during an appreciable period of time, it may give unsatisfactory service thereafter.

The trend seems to be away from both casein and urea glues for assembly work towards the entirely satisfactory phenolic. For assembly processes it would be highly desirable to have available low-temperature-setting phenolic resins.

Melanin glue, which approaches the properties of phenolic resin, sets at 240° F. There is also a glue, manufactured by the Bakelite Corporation, which sets at about 240° F., which seems to be suitable for aeroplane-assembly work.

A number of heating processes have been tried out with fair success. Thus, high-frequency alternating current may be used with a condenser formed by two metal plates, with the spar or other wood part constituting the dielectric medium in between. The rapidly alternating electric wave passing through the wood produce local heat of the required intensity. Another local heating process using electricity is the so-called strip-heating process, with an electrical resistance coil surrounding or boxing in the joint to be glued.

Enough has been said to indicate that a vast field of research is open in gluing of parts and assembly work. Another question deserving of study is the bonding of plywood to metal, where a difficulty arises, because the two materials offer different resistance to the penetration of the adhesive. Some designers have expressed doubt as to the fatigue characteristics of a part or panel in which plywood is glued to metal.

The gluing of wood and metal together under pressure, with simultaneous or subsequent application of high temperatures, may lead to another difficulty. The isotropic metal expands in two directions with equal coefficients of temperatures. The non-isotropic plywood has varying coefficients of expansion. The results may be an internally stressed unbalanced panel, which reduces its ability to take up stress subsequently. A pressing problem is in the moisture and temperature control of the aeroplane plant where plywood or wood parts are being assembled. The hot-gluing on assembly also constitutes a strong argument for plant air conditioning, if healthy working conditions are to be retained.

Special Fabrication Processes.

By special fabrication processes, we really mean bag-moulding processes of one species or another. In

this technique thin strips of veneer are glued over a mould, with subsequent submission to pressure through a rubber bag in a steam-heated cylinder. These processes in reality are quite old in the woodworking art, and recent work has been more in the character of improvements over earlier processes. A whole series of problems remain still to be solved :

(*a*) Moulds of wood appear to be quite satisfactory for short periods of use, but have to be replaced by metal for longer runs. They are, on the whole, quite expensive, and have the disadvantage in that, once built, they cannot be readily modified. Hence the use of the bag-moulding process is not likely for aeroplane types which may have to be changed, following reports of service experience.

(*b*) For a large part, such as a fuselage, with compound curvatures, veneer has to be carefully tailored to the job, cut in thin strips, carefully laid by hand over the mould, considerable skill being involved. The heated cylinder takes up a good deal of room, and involves a considerable investment. The "cooking" process following on the tailoring is astoundingly rapid, but the impression that bag-moulding gives the most rapid production possible is erroneous. Greater rapidity in the tailoring and other parts of the technique would be desirable.

(*c*) Because the tailoring process may involve a period of, say, twenty-four hours in a large and complicated part, the glue must be such that it can be applied cold and retain its adhesion properties for a long time. Glues that are most satisfactory during the fabrication process are apt to lose their strength in service under severe conditions of temperature exposure. Practical research is needed to make sure that the glue best fitted for the fabrication process will retain its strength indefinitely in service. This point alone explains the reluctance of Army and Navy Air Services to accept the construction for combat aeroplanes (although the service record and behaviour under machine-gun fire of the British Mosquito bombers, which are built entirely of wood and plywood, may serve to remove this prejudice).

(*d*) The life of the rubber of synthetic-rubber bags employed in bag-moulding operations is only fifty hours. A substitute material is urgently needed and is being sought.

Plywood Components of the Aeroplane Fittings and Connections.

There are a number of practical points in the construction of aeroplanes which need experimental design and testing. Representative problems are :

(*a*) In aluminium construction the almost classical formulæ now is to employ a thin sheet metal covering, two or three spars or vertical webs, and to reinforce the skin with stringers or stiffeners. This practice has been carried into wood or plywood construction in spite of the fact that the lighter plywood covering could have a much greater moment of inertia and local stiffness for the same weight per square foot, so that stiffeners might be dispensed with and wing or fuselage, or both, be converted into true monocoque or shell structures.

(*b*) In the plywood wing with skin covering and two spars, let us say, which is a conventional type of construction, the outer panel is apt to be connected to the centre panel through hinges and appropriate fittings. At such a time, considerable concentration of stress is apt to be encountered, a concentration of stress for which wood and plywood are not so well fitted by their allowable bearing stresses, and because high bearing stresses may lead to distortion even if there is no failure It would be an interesting design problem to use compreg or other densified wood at such points both for flanges and webs, both for solid and veneered parts.

(*c*) In the same type of construction the skin, of course, takes up a part of the bending moment in tension on the lower surface and compression of the upper surface of the wing. The stringers act in a similar manner, and the skin also takes up shear, due to the torsion which is likely to be acting on the wing. A difficulty arises in transmitting stresses from stringers and skin indirectly to the hinge pins which so frequently carry the loads of the outer wing panel. The designer must decide whether he will require skin and stringers to be connected to an end bulkhead which will take up torsion and convert it into bending moment, or provide a metal box at the inner end of the wing, or resort to some other expedient.

(*d*) Ribs and spars have become conventional in plywood construction, but it is not true that design problems relating to these parts have disappeared. For example, in the spars, which are so tempting to construct as box beams, weight is added because the flanges come too near the neutral axis. In the ribs, lightness of construction is secured by diagonal-web trussing and small gussets at each end of the diagonals connecting them to the cap strips. But the high strength-to-weight ratio of the ribs is secured at the expense of a multiplicity of parts, and difficult fitting of parts which militate against speedy production.

Aeroplane Construction and Assembly in Relation to Plywood.

The assembly of wood-construction aeroplanes in some respects offer exactly the same problems as the assembly of a metal aeroplane ; its fixtures are the same, but jigging and connections are totally different in character. In metal aircraft, we use welding or riveting, while in the wood aeroplane assembly is mostly a question of gluing and holding down plywood over a wooden structure or form by nailing or nailing strips anf gluing by the cold-gluing process. Research here lies in the effort to accelerate assembly by the use of powerful presses and heat effects. If a manufacturer is willing to jig or tool up, if not the wing, then at least for the fixed or movable auxiliary surfaces, he will find it possible to realize astounding savings in time and expense. Of course, there are two important difficulties: (1) the possibility that the workroom may become very hot and necessitate expensive air conditioning ; (2) the very heavy initial investment.

Testing Plywood and Plywood Parts.

Practice in the testing of plywood itself is fairly well standardized, and requires no special consideration; where difficulties arise is in so testing plywood elements of an aeroplane that actual stress conditions are simulated, particularly combined stress conditions. So difficult does it appear to designers to simulate actual conditions in plywood elements that they very often prefer to test an entire wing panel, or a substantial portion of a wing panel. The drawback in testing a wing panel is that failures may occur in certain parts of the wing before information is gained on the strength of another element of the wing, although the latter information may be desired much more urgently. The pressing problem in testing technique is to simulate complex load conditions for parts of the structure.

Strength Properties of Plywood.

Wood and plywood may be in tension, compression, shear, bending, shear due to torsion, and under a combination of these stresses. Stresses may act in a number of directions for the same part, and the same part may in place be subjected predominantly to bending, in another to shear, as for example, the vertical

web of a box beam. The available data even for solid wood are meagre, and it is only a very few woods for which shear has been investigated. For plywood, the data are still more scarce, and the situation is complicated by the fact that instead of a small number of woods, we have an almost infinite number of possible veneer combinations to form plywood.

Another difficulty arises from the fact that, while the elastic theory of isotropic materials is well understood, the elastic theory of non-isotropic materials is less well understood and more complex, and the elastic theory of plywood is even more complex, because plywood involves the combination of a variety of non-isotropic materials.

Plywood manufacturers have done some work, but without any degree of completeness; aeroplane manufacturers have done a great deal of testing, but without attempt at system and mainly to acquire data for immediate design needs, testing a particular type of plywood for use in a particular part of the aeroplane. The Forest Product Laboratory has probably done more work than any other organization, but even the work of the Forest Products Laboratory has merely scratched the surface of the subject.

Opportunity exists, therefore, for theoretical investigation; for the testing of plywood as a material in various combinations of veneer, and for the testing of plywood in the many combinations of stresses and many uses to which it has been subjected in the aeroplane.

The first, and perhaps the most important, theoretical investigation would be in constructing a logical basis for computing the strength of any panel, given the strength and elastic properties of its component materials.

Whether or not it is possible to construct a rigidly accurate theory, it is difficult to say. At any rate, the theoretical work would take far too long. While the classical theory should be placed before the engineer in more palatable form, the better approach is to pursue the pioneer methods of Basquin, Norris, and others, and construct semi-theoretical, semi-empirical formulas, carefully checked by strength tests.

At least, for the woods entering most frequently into aeroplane construction, we should like to know all available strength and elastic properties, along the grain and perpendicular to the grain. What, for example, is Poisson's ratio for a panel? What is the combined modulus of rigidity in varying directions? How can strength and elastic properties be estimated when various angular direction for component veneers are employed? What are the properties of the panel when subjected to a combination of loads?

Structural Theory.

After many years of confusion, the structural theory of metal covered semi-monocoque construction of wings and fuselage has now taken fairly definite shape. When plywood construction is adopted, we have to begin all over again, though there is the advantage that the structural analysis of the metal structure is there to serve as an analogy. A great many research problems immediately impose themselves, of which the following are typical examples:

(*a*) In thin metal skin, the use of stiffeners is general. By partly empirical, partly theoretical methods, it is possible to determine what width of sheet in compression is co-operating with the stiffener, and what is the strength of the combination. One of our first tasks is to obtain similar methods of computation for plywood skin acting jointly with wood stiffeners.

(*b*) One of the arguments in favour of plywood is its much greater local stiffness for a given weight as compared with steel or even aluminium. If this argument is really valid, then in plywood the stiffener should disappear, and the construction should become purely shell or monocoque. Then we must learn to calculate the strength of a thin cylindrical shell under a combination of bending moment, shear and torsion.

(*c*) For metal, granted that we know the strength of a reinforced flat plate in edge compression, we can estimate the additional stress due to curvature of the plate or skin. Similar knowledge must be obtained for plywood, probably by the testing of plywood cylinders in edge compression. We must at the same time ascertain how such additional strength, due to curvature, is related to the composition of the panel.

(*d*) When does the ordinary theory of bending cease to apply? What happens if there is stress concentration? Are our usual theories applicable in such cases? Besides theoretical work, there would seem to be room here for the use of strain gauges, possibly embedded in the wood.

(*e*) We understand the buckling of a thin metal skin, whether it is in shear due to torsion, or in combined shear and compression, as on the upper surface of the wing. We even know under what torsional conditions the curved skin of the nose web will buckle or wrinkle. It is frequently said that, because of its greater thickness and local rigidity, plywood skin is not susceptible to buckling, and it is further said that it should never be allowed to buckle, even to the extent of the wrinkling which occurs in the tension-field beam. Both statements are incorrect. If a plywood structure is designed in refined fashion, buckling may become a very real problem, and if wrinkling (with subsequent disappearance of the wrinkles) occurs at very high load factors, then it will be admissible even in plywood construction. Hence both a theoretical and experimental approach to the buckling of plywood skin under various loading conditions is quite appropriate.

The committee has a splendid task before it in co-ordinating the work of many design, construction and laboratory organizations, and by such co-ordination and by synthesis to build up a body of knowledge comparable to that already existing for the all-metal aeroplane.

THREADS IN PLASTIC MOULDINGS

By Prof. Dr. A. Thum, VDI and Dipl. Ing. A Boden, Darmstadt. (From *Kunststoffe*, Vol. 32, No. 6, June, 1942, pp. 171-180).

Tapped threads in moulded plastics are often used in engagement with metal screws. Experiments under various stresses have been carried out in the State Department for Material Control at the Technical University in Darmstadt.

Concerning the strength properties of internal threads in plastic material, there has been hitherto little experimental data generally available, so that the designer has had to rely almost entirely on his own intuition. This was good enough, so long as plastics were applied only to lightly stressed components calling for neither the full load-carrying capacity nor minimum weight of material. But the more plastics are applied to highly-stressed and lightly-built parts, the more important it becomes to have reliable data for the design of an internal thread; for this, and with it the entire

moulding, are endangered by the fact that the thread is generally assembled with screws having strength properties up to ten times greater than the plastic; namely, steel, copper alloys and light metals.

Thus, the customary dimensions for other combinations such as light alloy with steel screws do not satisfy the requirements of technically and economically correct design. For this purpose the load-carrying capacity of the internal thread must at least equal and preferably exceed that of the cross-section of the bolt, so that any failure would occur in the generally more easily replaceable part, the screw.

Experiments were made to investigate how the strength of the threaded nut is influenced by

1. (*a*) Wall thickness of the nut.
   (*b*) Length of threaded nut.
   (*c*) Thread dimensions.
2. The strength properties of plastic material depending on
   (*a*) Type of material.
   (*b*) Moulding direction.
3. Strength properties of the bolt material.

Different experiments have been made to find out the effect of pre-stressing taking into account all other considerations which are valid for screwed joints of metallic materials.

The experiments included many tensile tests, using metal bolts screwed into moulded test pieces. The tests were carried out on a tensile testing machine, the applied force acting in a longitudinal direction tending to pull the threaded test piece off the bolt. Bolts of steel and aluminium alloy were used in the tests. The steel from which the bolts were made in some cases was standard steel of 44 tons per sq. in., ultimate strength. In some of the fatigue tests, however, the bolts were made from higher grade steel with an ultimate strength of 58 tons per sq. in., and in certain cases aluminium alloy with an ultimate strength of 28 tons per sq. in. These figures compare favourably with the strength of materials normally used in practice, and the results derived, therefore, are on the safe side. Threads used in the tests varied in diameter from 3 mm. to 12 mm., and in pitch from .5 mm. to 1.78 mm.

All the threads were tapped as there was no possibility of obtaining test pieces with moulded threads. As earlier experiements proved very little difference to exist in the strength between moulded and tapped threads, as far as unlaminated mouldings were concerned, the results can be taken to apply equally to tapped and moulded threads.

The threaded test piece thickness was generally identical with the thickness of the moulded test piece from which it was cut. To test the effect of length of thread engagement the bolts were screwed into the pieces different depths in different tests, and it was found that the extra unused thread in such cases made no difference to the results. The threaded test piece was mainly stressed by applying initial tension to provide the effect normal in practice when a nut is screwed down hard with a spanner. It was found that this ensured a more complete stress distribution along the threads in engagement.

The test bolts were always taken from the same batch and the test pieces were tapped with the same taps, so that the tolerances were as nearly as possible identical within the same type of thread. Tests were taken using tolerances in the "fine" class and in the "medium" class. Sufficient difference in results was shown to indicate a recommendation that close tolerances be adopted when dissimilar materials are used for nut and bolt, particularly where one of the materials has small inherent strength, as the stress on the threads was found to increase with larger clearances. Close engagement of male and female thread was found to be more important in these cases than if the bolt and nut were made of the same material.

Manufacture of the Test Pieces.

The threaded test pieces were prepared from 150 × 150 mm. moulded stock of varying thickness (Table 1.)

TABLE 1.

PHENSOLIC MATERIALS AND MOULDING CONDITIONS.

Type	Material	Resin % Content	Pressure T.P.S.I.	Mould Temp. °C.
S	Filler: wood flour	40	2.6	155
Z1	Filler: cell. flakes ..	45	4.2	155
Z3	Paper lamin. material	40	4.2	155
T2	Filler: cotton shreds	45	4.2	155

Curing time for all materials acc. thickness:

Thickness of plates 150 × 150 m/m.	10	15	16	20	25
Curing time in minutes	12	16	18	22	28

Most of the pieces were tapped parallel to the axis of compression, a few samples only being tapped perpendicular to the axis to investigate the effect of tapping. To avoid cracking it was found necessary to direction of tap the moulded sheets or stock through the whole thickness before cutting out the test pieces.

The plug tap only was used in tapping. When taper, second and plug taps were used the threads were not so clean cut. The reason for this was found to be in the difficulty of the second and third taps, "picking up" the thread already cut by the taper and second tap respectively, and the tendency is for the second tap in particular to cut a new thread out of pitch sequence to the former thread. Fig. 1 shows a clean thread cut with a plug tap in a general purpose material. Fig. 2

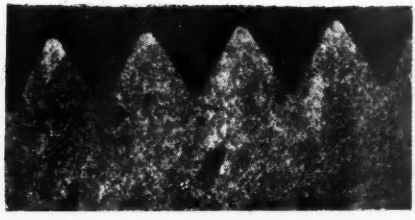


Fig. 1. Clean thread cut in wood filled material. Thread: Metric: 12 × 1.75 pitch. Enlarged 8×. Tapped by "plug" tap only.

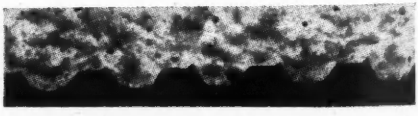


Fig. 2. The same thread and material as in Fig. 1, tapped by taper, second, and "plug" tap. Enlarged 7.2×.

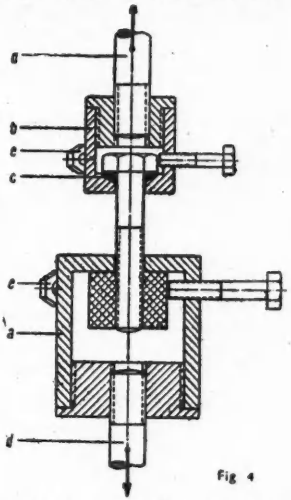
Fig 3

shows the same type of thread cut in similar material with a complete set of taps. It should be mentioned that a method of overcoming the trouble associated with cutting threads with a full set of taps can be

suggested. This is to make the taper and second taps of a set of three taps with a profile form possessing a greater angle than the plug tap (see Fig. 3); the cutting angle should be fairly acute, the taps should contain three large flutes, and the first and second taps should have a long lead.

Tensile Tests.

The apparatus used in the tensile tests is shown in Fig. 4. Eighty-eight different tests were carried out,



Fixture for tensile tests.

a Support for moulded nut.
b Support for screw-head.
c Ball-washer.
d Shank to fit tensile test machine.
e Fixing screw.

Fig 4

the time until fracture being controlled to a period of 3 minutes. The four materials given in Table 1 were tested with different threads, lengths of thread engagements, test piece thicknesses and outside diameters. The results are shown in Table 2, which incorporates the relative test piece dimensions as far as outside diameter, thread diameter, and length of engagement of thread, are concerned. It shows that, depending on

TABLE 2.

DIMENSIONS OF NUTS (THREADED HOLES).

Material Type	Thread Metric	D d.	T d.
S	3 mm. × .5 pitch ..	3	2
	8 mm. × 1.25 ,, ..	3.5	2.5
	12 mm. × 1.75 ,, ..	4	3
Z3	3 mm. × .5 ,, ..	2	2
	8 mm. × 1.25 ,, ..	2	2.5
	8 mm. × 1.75 ,, ..	1.8	1.5
T2	3 mm. × .5 ,, ..	2.5	3
	8 mm. × 1.25 ,, ..	2.5	3
Z1	8 mm. × 1.25 ,, ..	2.5	2.5

D .. .. Outside Dia. of Nut.
T .. .. Length of engagement (tapped hole).
d .. .. Top Dia. of Screw-head.

the material, both the outside test piece diameter and the depth of engagement of thread should be 2 to 3.5 times the bolt diameter to give the best results. In this respect, it was shown that there was a minimum wall thickness relative to thread dimensions below which the nut would break before the moulded threads were torn out.

Rather large variations were found in results when using material T2. The test pieces were moulded in a way that oriented the material fibres in some cases parallel, and in other cases perpendicular to the direction of pressure. It was found in test that the strength of the test pieces where the fibres were located perpendicular to the direction of pressure, was increased.

Influence of the Pitch.

Breaking of the test pieces occurred as a combination of the shearing and flexural stresses acting upon the threads, although not always in equal relation, depending upon the material and thread dimensions. It was found that the strength could be increased by increasing the length of thread engagement which not only increased resistance to shear, but increased resistance to bending also. However, the total length of engagement possible may be limited by consideration of economy and design in practice. With this in mind, tests were taken with threads of different pitch, and it was found, in general, that resistance to bending moment increased as the square of the pitch.

On the basis of earlier experiments, Mehdorn suggests the introduction of a special type of thread for plastics. The type suggested, as proved by these experiments, is one possessing a fairly course pitch, similar to that of a wood-screw, but with a constant diameter (something similar to the self-tapping screws now in use). With such threads a 16% increase in load-carrying capacity was found.

According to my own tests, which the above results (Mehdorn) confirm, on type Z3 with 8 mm. threads of varying pitch, fine threads do not seem suitable for plastics. Even with a depth of engagement t=3d, and D=15 mm., the test piece thread-strength did not reach carrying capacity of the bolt. Whilst the breaking strain for the bolt was about 5,290 lbs., the test piece was only able to stand about 3,750 lbs. On the other hand, with a standard metric thread, t=3d and D=15 mm., it needed a load of about 4,740 lbs. to produce failure of the test piece. With threads of larger pitch than 1.75 mm. failure occurred with the bolt on account of its small core diameter. In such cases, the bolt broke with a load of less than 4,144 lbs. Tests were made to determine what reduction in dimensions of test pieces could be made, and still retain a thread with a carrying capacity at least equal to the bolt, and it was found with a 1.75 mm. pitch and D=15 mm., a reduction of t to 1.5 d could be made without reducing the strength lower than 4,140 lbs. Fig. 5 shows this clearly, illustrating the ultimate strength in relation to length of engagement, pitch, and bolt material.

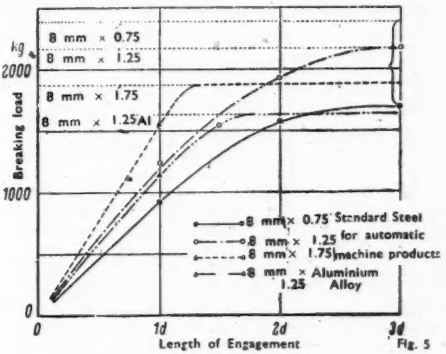


Fig. 5

Breaking load in relation to length of engagement *t*, pitch, and screw material. Plastic material: laminated paper. The horizontal dotted lines show the breaking loads for the screws.

Influence of the Press Direction.

Experiments were made to test the effect of tapping in holes perpendicular to, and parallel to, the direction of pressure. It was found that the direction of pressure has no effect on strength with general purpose wood-filled materials, as threads tapped parallel to the direction of pressure were found to have the same carrying capacity as holes tapped perpendicular. With laminated materials, however, the strength of threads tapped parallel to the direction of pressure was found to be higher than of threads tapped perpendicular to it. It was also found that tapping became difficult perpendicular to the direction of pressure. In tests on laminated materials with cellulose or cotton base, threads tapped perpendicular to the direction of pressure showed between 11% and 23% lower strength than was found with threads parallel to the direction of pressure.

Influence of the Bolt Material.

Previous mention has been made regarding the fact that the table bolt material was of high strength, and the dimensions in Table 2 are obtained from such experiments. It is emphasised therefore, that these figures are on the safe side. When using steel or light alloy bolts of lower strength than used on the test, the dimensions D (outside diameter of test piece or boss) and t (length of thread engagement) may safely be reduced, compared with the dimensions given in the Table.

Experiments under Combined Stresses.

For all intents and purposes, the tensile tests can be taken to represent the results when the stresses are acting in an axial direction. Under practical conditions, as already mentioned, there are additional stresses resulting from the torque due to tightening the bolt. A rather intricate apparatus was constructed, therefore, in order to measure and control the effect of the stresses acting as a result of the twisting moment due to tightening. Load was applied in an axial direction to bring conclusion to the test. The total load was steadily and gradually applied up to the point of fracture within 3 minutes. It was found that nuts which stand up to the tensile test will equally withstand tests under combined stresses, to a proportionate degree.

Fatigue Tests : Endurance Limits.

Tests were taken to determine the effect of fatigue under load, over a length of time. The cold flow of the plastic material, however, resulted in the falling of initial tension amounting to 7% within 5 hours, and 12% after a longer period. It was found necessary, therefore, to arrange to keep the initial tension constant during fatigue tests.

The final fatigue test, therefore, showed comparative results in the same degree against fatigue as was shown against tensile. Owing to the high specific pressure on the friction face (a specific pressure of 7.5 tons per sq. in., was measured), the use of washers between plastic material and metallic nuts is recommended.

RESISTANCE WELDS WITH ELECTRONIC CONTROL

By T. R. LAWSON. (From *Westinghouse Engineer*, Vol. 2, No. 4, November, 1942, pp. 109-113).

ELECTRONIC control eliminates the shortcomings of the mechanically controlled resistance welds in that the current to the weld can be precisely determined in addition to limiting accurately the duration of its application. These factors, together with definite pressure control, especially in certain non-ferrous alloys, determine the quality of the weld.

One of the principal factors that delayed the general acceptance of electronic control was lack of complete reliability of the equipment through short-lived electronic tubes and other associated equipment. In the past several years, however, the increased life of the ignitrons and the use of heavier, more rugged resistors, capacitors, potentiometers, etc., have achieved an excellent consistency of operation.

The welding operation is tantamount to short-circuiting the secondary of a high-current transformer through the metal as shown in Fig. 1. Accurate control of the following functions must be maintained to prevent the burning or warping of the metal and sticking of the electrodes : (1) the amount of current passed through the work, (2) the time this current is allowed to flow, and (3) the time and amount of electrode pressure.

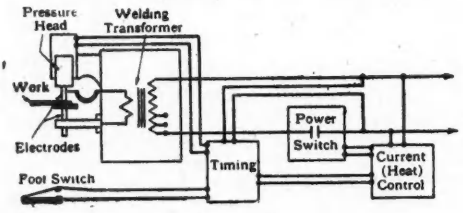


Fig. 1. With the two principal controls shown, timing and current control, closing the foot switch sends the welding machine through the complete cycle, precisely determining the on, squeeze, and off times, the magnitude of the current, and its duration to a fraction of a cycle, with consistent exactitudes.

The control required to perform these functions satisfactorily can be divided into broad classifications as follows :—

1. Single-phase a.-c. welding—
   (*a*) Non-synchronous, (*b*) Synchronous.
2. Three-phase stored energy a.-c. welding—
   (*a*) Magnetic, (*b*) Capacitor or electrostatic.

Single-Phase A-C Control.

A non-synchronous control permits random closing of the single-phase power circuit by pushbutton, mechanical timer, or foot switch. Such random operation results in momentary abnormal current peaks dependent in magnitude on the part of the wave at which the circuit is closed, as shown in Fig. 2 (*a*). These uncontrolled fluctuations cause changes in the amount of heat supplied to the weld during the first few cycles. Hence there is undesirable variation in weld quality, especially on short-time welds of a few cycles. On longer welds, say, up to 20 or 30 cycles, the transient condition is a small percentage of the total energy used and therefore does not greatly affect the quality of the weld.

A synchronous control closes and opens the power circuit at the same point on the voltage wave for every weld so that the high transients are eliminated, Fig. 2 (*b*), and more consistent welding obtained. There is no ironclad rule when to use synchronous control. However, certain general recommendations can be followed:

1. The shorter the weld time the more necessary synchronous control becomes. Non-synchronous ones should not be used for welds shorter than about four or six cycles, if consistent results are expected.

2. Certain materials difficult to weld, such as aluminium, brass and stainless steels, require synchronous control.

3. When highest quality welds are required, either for uniform spot size and strength, or good metal surface appearance in any metal, synchronous control is used.

4. Non-synchronous control should be used

principally for mild steel and long-time welds when minimum first cost of equipment is more important than highest weld quality.

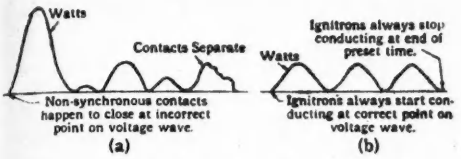

Watts
Contacts Separate
Non-synchronous contacts happen to close at incorrect point on voltage wave.
(a)
Watts
Ignitrons always stop conducting at end of preset time.
Ignitrons always start conducting at correct point on voltage wave.
(b)

Fig. 2. Synchronous and non-synchronous controls compared.

Non-Synchronous Control.

An electronic control in widespread use for non-synchronous welding consists of a single-pole ignitron tube "contactor" used to make and break current as high as 8,000 to 10,000 Amp. rapidly without arc, noise, or moving parts. It is known as Weld-o-trol, and is applicable (within its rated limits) to any a.-c. resistance welding machine as the device that connects the primary of the welding-machine transformer to the a.-c. line.

The heart of all electronic devices that handle the heavy current of a.-c. resistance welders, is the two ignitron tubes (Fig. 3). An ignitron is a heavy current-carrying mercury-arc-rectifier tube with a special igniter firing device. Each tube passes alternate half cycles of current to the primary of the welding transformer as long as the ignitron circuit is energized. Selection of ignitron tube size is based on the maximum current drawn and the duty cycle imposed.

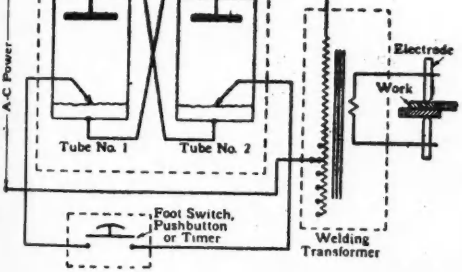


Fig. 3. Two ignitions used in full-wave rectifications. The control switch is placed in the special igniter circuit of these heavy-duty mercury-vapour rectifiers for exact current control.

One advantage of the ignition over mechanical contactors in resistance welding is the extremely fast speeds at which it can operate. Having no moving parts, it readily makes and breaks currents of several thousand Amperes 600 times per minute. Also of great importance is the accuracy with which it can be timed, and the fact that the amount of current passed by the tube can be smoothly controlled. In addition, when ignitron tubes are used to carry the current to a resistance welder, an electronic current (heat) control device can be used.

Heat control uses two thyratron tubes to make or break the igniter or firing circuit of the ignitron power tubes. The control of the ignitron current is achieved by shifting the phase of the thyratron grid voltage with respect to the line voltage (Fig. 4). This grid voltage is

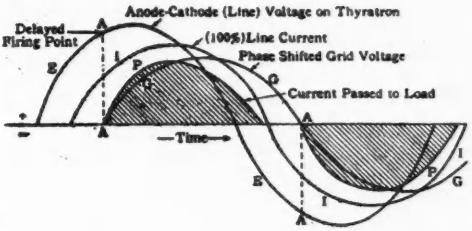


Fig. 4. Limiting load current by phase control. (Assuming, for the simplicity of illustration, that the critical grid voltage of these thyratron tubes is along the zero axis, when the a-c voltage, curve G, applied to the grid is positive, the thyratron tube will fire. Therefore, by shifting the position of the curve G, the thyratron can be made to pass current at any point in the voltage wave, E.)

the result of a resistor-reactor circuit. By varying the amount of resistance in the circuit by means of a potentiometer the phase position of grid voltage can be shifted (Fig. 5).

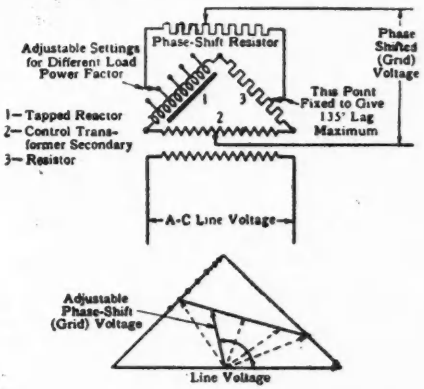


Fig. 5. Schematic and vector diagrams of the method of phase shifting of the grid voltage by means of a variable resistor.

The Weld-o-trol and heat control apply and control the magnitude of the current to the welding transformer. There still remains to be controlled the duration of weld current and the electrode pressure and sequence.

Some resistance welders use manual- or motor-operated electrodes with cams to start and time the weld current. On such machines automatic weld timers are not required. When air- or hydraulic-operated electrodes, with solenoid-operated valves are used, weld timers are employed to time the duration of current flow, and also to time the electrode sequence. Electrode pressure is determined by regulators normally a part of the welding machine proper, rather than a function of the control device.

The nerve centre of an electronic automatic weld timer consists of one or more small thyratron tubes acting to operate small, lightweight, fast-operating relays which in turn control the primary-line contactor or Weld-o-trol. The thyratron is a three-element electronic grid-control tube, used to control other units handling heavy currents. In the case of the Weld-o-trol it energizes the igniter circuit of an ignitron, and in

the case of a magnetic contactor it energizes the coil. The relays in the timer also control the solenoid valve in the welding-machine head. Normal timing intervals of 3/60 to 6 seconds are obtained by adjusting the resistance in a resistance-capacitor time-delay circuit applied to grids of thyratron tubes. Any or all of the following functions can be controlled by such an electronic timer, usually requiring one thyratron tube and one relay with accompanying adjusting potentiometer for each function.

1. Squeeze time: The duration of time from application of electrode pressure until application of welding current.

2. Weld interval: The total "heat" and "cool" times, or total welding cycle, when welding by pulsation method. In pulsation welding, current is applied to one spot in a series of spaced, short periods (from a fraction of a cycle to ten or more cycles), the length of the individual period depending on thickness of material, type of weld, etc. The pulsation method is used to avoid excessive heat on the external surface of the metal while maintaining welding temperature at the juncture of the metals to be welded.

3. Hold time: The time that pressure is maintained at the electrodes after the current is cut off.

4. Off time: The time, in repetitive welding, that the electrodes are separated from the work piece.

An automatic weld timer to perform all of these functions is contained in a cabinet only 12 by 17 by 12 inches.

Synchronous Control.

This term, for single-phase welding, generally applies to several combinations of power tubes and control elements for both spot and seam welding. In all cases the control is arranged so that the ignition tubes cannot fire ahead of the zero point on the supply-current wave. In addition, a weld-timing circuit is incorporated on all synchronous controls (normal range 1/60 to $\frac{1}{2}$ second), and therefore, the weld-time need not be controlled by a separate device as outlined for non-synchronous control. However, the order of sequence of the electrodes is handled by a small electronic sequence-timing panel as a unit separate from the main synchronous control. The construction and operation of the sequence panels used with synchronous controls are identical with the non-synchronous automatic weld timer, except that the weld-time feature is not required.

Spot-and-Seam-Welder Types.

Many synchronous controls for spot and seam welding are doing a specific production job; others require a flexibility of application, and a variety of synchronous control combinations has been developed by manufacturers. There are two types of seam-welding timers, one partially mechanical and the other fully electronic.

The partially mechanical one has chain or disc timing. In the disc type, pins inserted in the synchronously driven disc pass through a magnetic field, and this magnetic field variance, by means of an electronic device, controls the number of cycles the current flows and is off, respectively. A pinhole is provided for each half cycle. The chain type operates on a contact system. A series of spaced metal buttons on a chain driven at constant speed makes contact with a stationary element, and provides the timed impulses that motivate the controls. Between the metallic buttons on the chain are placed insulating spacers. The timing is achieved by varying the number and the spacing of the metal buttons.

Thus, by either system, while work is rolling through seam-welding electrode wheels, a stitching effect is simulated. Heat is applied intermittently, and a row of spot welds made.

The completely electronic type of seam timer is entirely electrically operated, and in addition to seam timing, this unit is arranged to permit quick and accurate conversion to spot or pulsation welding. To change timing, it is merely necessary to change the timing dial to the desired number of cycles on and off, whereas the mechanical controls are made only for seam-welding.

Energy Storage Control.

In single-phase welding the energy is taken direct from the a.-c. line through a transformer, whose secondary is essentially short-circuited. Thus the load imposed on the single phase system consists of many high current peaks of short duration and low power factor. To reduce these peaks, and to provide other desirable features not found in single-phase resistance welding, methods of welding with stored energy have appeared, and are used at present primarily for welding aluminium. Their basic principle is to draw energy slowly from a three-phase line and store it until the weld is made. In some cases, this storage method has reduced peak kVA 80%. The two types are the magnetic one, which stores energy in the iron core of the welder transformer, and the capacitor type, which stores energy in a bank of capacitors.

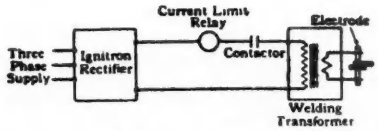


Fig. 6. D-c energy is stored in the transformer circuit until released by a current-limiting relay at a preset value.

In the magnetic type (Fig. 6), d.-c. energy is stored in the magnetic circuit of a transformer. Power is taken from a three-phase line and rectified by ignitrons, which operate solely as rectifiers. The electrodes close and apply pressure, and the contactor is closed. The current then builds up over a period of several cycles in the primary of the welding transformer. When it reaches the point for which a current-limiting relay has been set, the relay opens the contactor. The rapid decay of current in the primary causes a high inductive current in the secondary. It is this current which makes the weld. If the current-limiting relay is accurate, an identical current will be produced in the weld every spot, regardless of line voltage fluctuations.

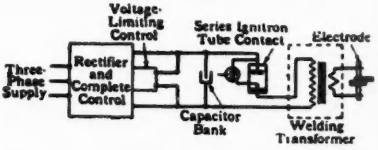


Fig. 7. Here, d-c is stored in a capacitor bank and released at a predetermined voltage into the transformer circuit.

In the capacitor type, Fig. 7, energy is taken comparatively slowly from a three-phase line, and rectified to furnish d.-c. charge a large capacitor bank. Here, a predetermined voltage setting is reached, which may be from 1,000 to 3,000 volts, and maintained by a trickle-charge scheme until the operator presses the initiating switch to make a weld. This contact allows the series ignitron used as a line contactor to fire, discharging the capacitor bank into the transformer and giving one unidirectional current pulse for each spot, regardless of line voltage fluctuations.

A-C Control versus Energy Storage.

The first cost of the single-phase control is much lower than that of the energy storage. Single-phase control has been developed over an extended period, and is simpler in design and construction. Resistance-welding operators are more familiar, in general, with a.-c. control.

In spite of its comparative newness, energy-storage control has proved its advantages. It provides a balanced three-phase load instead of single phase, with much lower peak kVA demands, and with improved power factor. Smaller conductors can be used for power supply. More consistent results in welding Aluminium for the Aircraft industry are claimed because: (*a*) the weld is made with measured energy; (*b*) line-voltage variation does not affect the energy applied to the weld; (*c*) electrode "pick-up" is less with accompanying longer electrode life; (*d*) forging action can be applied to heavier gauge welds helping to prevent cracks in the metal.

Whereas single-phase control is well developed, the development of energy-storage control is far from completion. Its present more complicated design, quickly developed because of the need for control in the aircraft industry, will undoubtedly be greatly simplified.

ELECTROSTATIC HIGH-FREQUENCY HEATING MAKES POSSIBLE MANY NEW DESIGNS

By PAUL D. ZOTTU. (From *Product Engineering*, January, 1943, pp. 40-43.)

OPERATING on a principle entirely different from that employed in high-frequency induction heating, electrostatic heating has now paved the way for many new design possibilities. In high-frequency induction heating, the high frequency magnetic field creates eddy currents in the metal being heated. The eddy currents are dissipated and converted into heat at or near the surface of the metal, and the higher the frequency, the shallower is the heating effects. Because high-frequency induction heating depends for its operation upon the development of eddy currents, it can be applied only to metals, or more strictly speaking, electrical conductors.

As materials that are poor conductors of electricity are also poor conductors of heat, it is necessary that any process for heating non-metals must be capable of heating the whole mass at a uniform rate throughout, if the whole mass is to be raised to the same temperature. The desirability for such a type of heating has been most pronounced in the plastic industry.

Because of its low rate of heat conductivity, it is impossible to heat a plastic material uniformly throughout when employing the usual means of heated platens. The material near the surfaces are overheated while the interior is still relatively cool, a condition which becomes worse as the thickness of the plastic material increases. The same difficulty is encountered in the manufacture of laminated plywood, wherein thermosetting glues are used for the adhesive. Up to this time it has been uneconomical to produce sections of laminated plywood

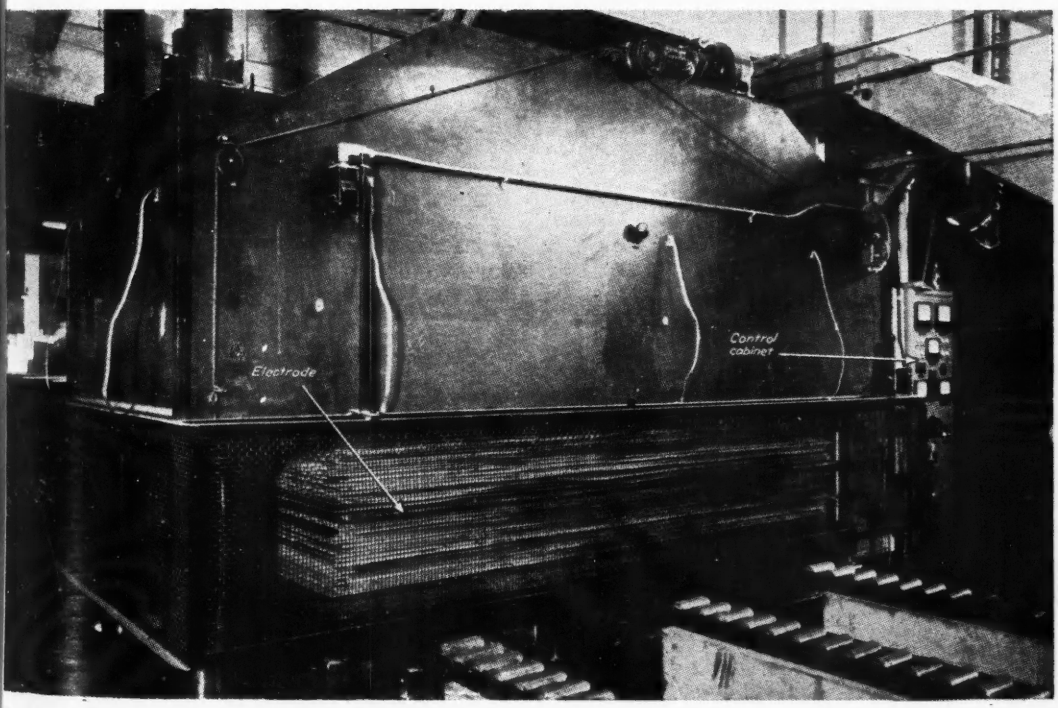


Fig. 1. Press equipped for electrostatic heating making a thick slab of resin bonded plywood. The control cabinet to the right houses all of the electrical apparatus.

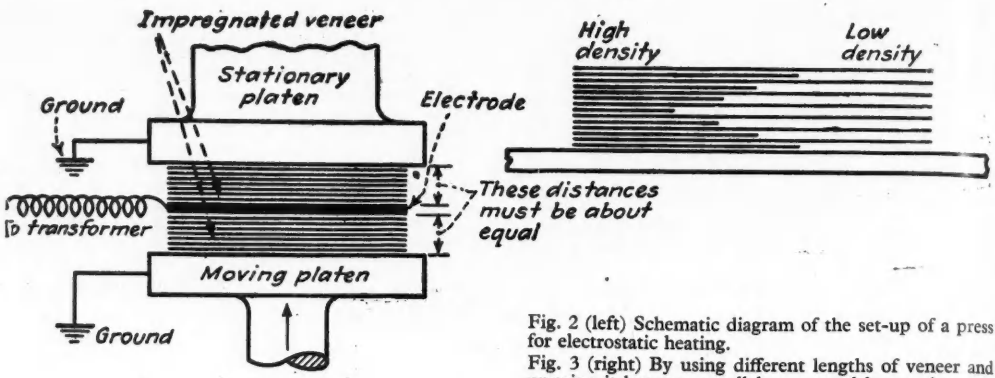


Fig. 2 (left) Schematic diagram of the set-up of a press for electrostatic heating.

Fig. 3 (right) By using different lengths of veneer and pressing it between parallel upper and lower platens, a material of varying strength and density is obtained.

thicker than about 1 in., because of the impossibility of effectively setting the adhesive in the interior before the resin near the surfaces became overcured.

With resin impregnated material a large percentage of the weight of the complete product is due to the impregnating resin. When the hot platen of the press in the conventional process comes in contact with the impregnated material, the thermosetting reaction begins. This process is exothermic, liberating heat and causing the temperature to rise over and above the temperature rise produced by the hot platen. The heat liberated, plus that received from the hot platen frequently causes overcuring of the product.

These limitations have now been eliminated by the high-frequency electrostatic heating as produced on thermal equipment of the Girdler Corporation. The product being heated, which may be plywood, plastic moulded parts, rayon filaments, or other non-conducting material, serves as the dielectric of a condenser. The electrodes of the condenser may be two conducting surfaces, one on either face of the material. In Fig. 2 is shown the set-up for simultaneously heating and pressing layers of plywood stacked in a press. The electrode consists of a piece of sheet copper or any other metal sandwiched between thin layers of plywood or other similar non-conducting material. The electrode is connected to one terminal to a high-frequency transformer. The other terminal of the transformer is connected to the upper and lower platens of the press. The entire press is maintained at ground potential. A voltage of some thousands at a frequency of 1,500,000 to 10,000,000 cycles is then applied.

In installation up to 15kVA the electrical equipment furnishing the heating energy is all contained in a cabinet which is placed wherever convenient in the vicinity of the press. As shown in Fig. 1 the cabinet may be relatively small. The apparatus in the cabinet includes switch gear, transformers, rectifiers, oscillators, power amplifier and all the necessary accessories, such as coils, condensers, etc.

With the exception of an air blower, there are no rotating units or machines involved, hence maintenance is not difficult. When power is applied the heat generated is not produced by a hysteresis effect as in the high-frequency induction heating of metals, but is generated as a result of the agitation of the molecules when subjected to the high-frequency field. One explanation is that the effect of the high-frequency is such as to make the molecules repeatedly change their shape. On applying the electric field a spherical molecule may be thought of as being deformed into an ellipsoid. The frequency of the applied electric field determines the number of times the molecule is deformed per second. This energy of agitation is converted into heat. Basically, the principle of operation is the same as that used by some diathermy machines.

Because the material is heated uniformly throughout, practically any thickness of laminated plywood can be made and all of the glue layers will be cured uniformly. As an example, 148 sheets of impregnated birch veneer have been glued by this process successfully, using a phenolic resin adhesive. By test, the impregnated compressed birch block of 148 laminations was found to have a tensile strength of 45,000 lb. per sq. in., and its specific gravity was one-half of that of aluminium.

By using different lengths of veneer as shown in Fig. 3 and pressing this between the upper and lower platens which remain parallel, a material of varying density is obtained. At one end of the cross-section, the material is highly dense and correspondingly stronger, and both density and strength decrease toward the other end of the cross-section as indicated. This enables the design of beams of varying strength to meet certain load conditions. Such a construction also presents great possibilities for application where the member is subjected to centrifugal force. The low density material is placed near the periphery of the wheel, while the high density and stronger material is at the hub, e.g., airscrew blades.

This process is not limited to the moulding of parts having plane surfaces. The only basic requirement is that electrodes shall be essentially a uniform distance apart at all points. Parts having curved surfaces can be readily made if the section is of approximate uniform thickness. If a shape such as the leading edge of an aeroplane wing is desired, a wooden die block, as shown in Fig. 4, is first constructed. The interior surface of the wooden die block is sprayed with metal and thereby

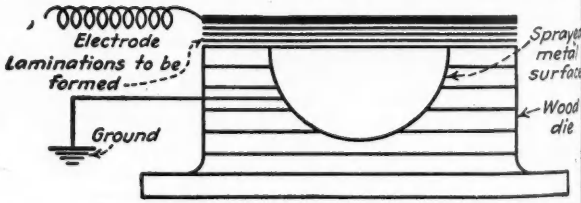


Fig. 4. Set-up for making the leading edge of an airplane wing

serves as one of the electrodes. A corresponding male die is made. The adhesive coated plywood sheets are placed on top of the female die and a thin sheet of metal to serve as the other electrode is placed on top of the veneer. Pressure is applied, the wood sheets are forced into the female die, the electrical power is applied and in a few minutes the adhesive is cured uniformly throughout.

Scale models of two keels for high-speed boats were made. The one keel was made of solid wood which required a lap joint. The other was a one-piece plywood construction made by the Thermex process. The curves in Fig. 5 show the results of the tests on these constructions. It is significant that the wood construction failed in every respect, namely, by tearing apart on the tension side, buckling on the compression side, a shear failure through the wood at the connecting bolts (Fig. 6). The plywood constructions failed by

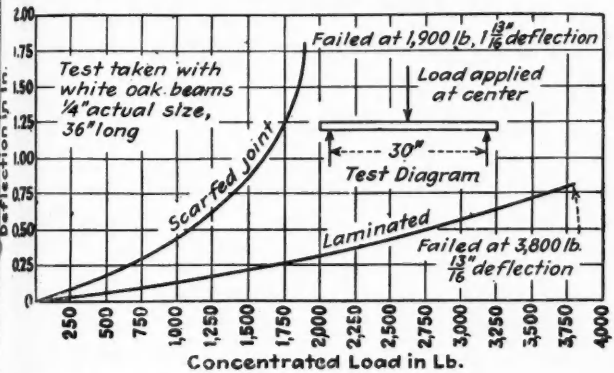


Fig. 5. Load-deflection curves of tests on two one-quarter size models of keels, one a white oak beam with bolted lap joint, the other a one-piece plywood construction.

horizontal shear, indicating that in both cases the design was the optimum.

There are no critical factors involved in the electrostatic heating process, and it is quite simple to calculate the time and energy requirements. It is merely necessary to know the weight and specific heat of the material to be heated and the temperature rise required. This will determine the amount of heat that must be delivered into the material. For example, if a 100 lb. block of wood is being treated and its specific heat is 0.45, it will require 45 B.t.u.'s to raise the temperature of the wood 1 deg. F. If the temperature of the wood when put in the press was 70 deg. when the current was turned on and the final temperature is to be 220 deg. F., the temperature rise will have to be 150 deg. and hence 45 B.t.u. per deg. × 150 deg., or 6,750 B.t.u. will be the amount of heat required.

If, in this operation, the power input of the heating equipment is at the rate of 25 kW and assuming an overall efficiency of the equipment is 50 per cent., which is about what it is, the rate of heat generation in the wood will be 25 kW × 3,413 B.t.u. per kW. hr. × .50 or, in round numbers, 42,500 B.t.u. per hr. as generated in the wood. As the heat required to raise the temperature of the block of wood to 6,750 B.t.u., it will take about 0.16 hours, or 9.5 min. to heat the block of wood to the desired temperature of 220 deg. F. Output capacities of the units available range all the way up to 500,000

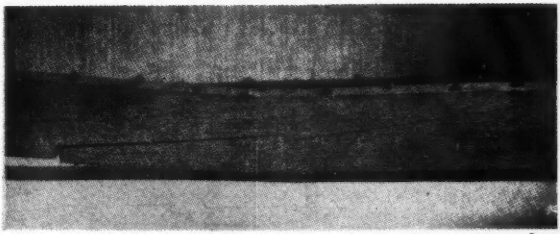


Fig. 6. Failed joint in solid oak keel that was loaded as a simple beam. Upper fibres crashed, lower fibres failed in tension and the wood sheared at the end bolts.

B.t.u.'s per hr. The actual capacity of equipment and power input used is such that the whole process will be completed in a few minutes. In the above example, a 100 kW input machine would complete the whole operation in less than 2½ minutes.

Suitable instruments on the heating equipment keep the operator informed of the rate of electrical energy input and time. Controls are complete so that the operator can use any output desired up to the whole output of the machine. Effective protection and safety devices are incorporated in the equipment to insure complete protection to both the operator and electrical performance. The application of electrostatic heating is not limited to manufacture of plywood. Practically any non-metallic material can be heated in a high frequency electrostatic field.

A table of materials that could be heated by electrostatic heating would include all types of cellulose, paper, textiles, powders, felts, leather, wools and cottons, ceramic clays, oxides, tobacco, rubber, celluloid, glass, fibre-glass and granulated cork.

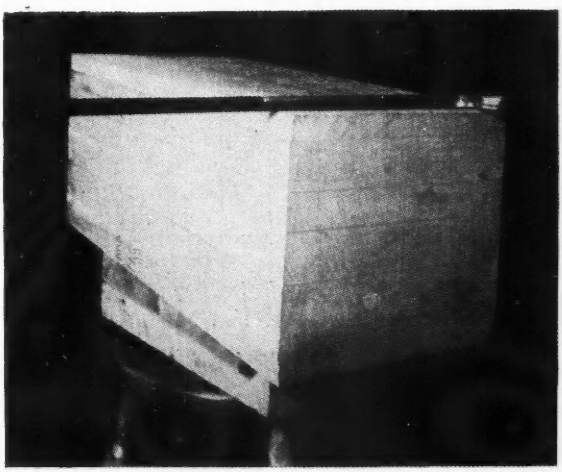


Fig. 7. Block of laminated white oak bonded by electrostatic heating. It is about 10 in. square, too thick to be made by usual methods.

Undoubtedly, there are many further applications which have not yet been investigated. The process can also be used for sterilizing cereals and other foods.

Among the mechanical constructions that have been made by the use of high-frequency electrostatic heating are airscrew blades, spars, ribs, wings, assemblies. Also, keels, main frames and transoms for ships.

With reference to productive capacity, two 30(kW heating units are equivalent to at least three hot plate presses, each having openings and with automatic loaders. One electrostatic heating unit will easily handle the output of two modern veneer glue spreaders working continuously.

ELECTROSTATICAL CHARGES ON DRIVING BELTS

By DR. A. BECKER, Leipzig. (From *Werkstatt und Betrieb*, Vol. 75, No. 6, June, 1942, pp. 132-135).

ELECTRICAL charges on driving belts are highly undesirable as they may impede the serving of any machine with not perfect earth connection, and as they constitute an acute danger in chemical and various other factories where explosive vapours may come forth.

Two methods were used for investigating the nature of these electrostatical charges, and the influences they are subject to, firstly, by measuring the voltages reaching sometimes as much as 30 kV, and secondly, by measuring the electrical current taken off the belt by pointers. This second method yielded the better results. The investigations were facilitated by the publication of two reports about experiments on band-generators. (W. KOSSEL: *Investigations on Electrostatical Machines, Zeitschrift fur Physik*, Vol 111, No. 3 and 4, 1938, p. 264).

The current taken off the belt by comb-like pointers is:

$$i = \sigma.b.v. \quad .. \quad .. \quad (1)$$

σ being the density of the charge, v the speed of the belt, b the width of the comb. From equation (1) follows the density of the charge

$$\sigma = \frac{i}{b.v.} \quad .. \quad .. \quad .. \quad (2)$$

The upper limit of the density is set up by the breakdown field strength E_D of the atmosphere, which can be assumed to: $E_D = 30$ kV/cm. With this value for E_D, the upper limit for the current i, which can be taken off the belt, is

$$i_{max} = 0.266 \,.\, b \,.\, v \,.\, 10^{-6} \text{ Amperes} \quad .. \quad (3)$$

if b in cms and v in m/sec. This is the basic equation for the further investigations.

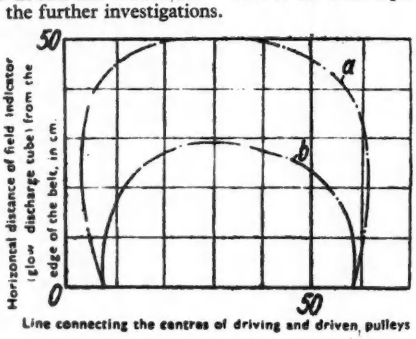

50
a
b
0
50
Horizontal distance of field indicator (glow discharge tube) from the edge of the belt, in cm
Line connecting the centres of driving and driven pulleys
Distance from centre of driven pulley, in cm

Fig. 1. The electrostatical field produced by a 60 mm. wide and 4 mm. thick leather belt (measured in the plain through the centres of the pulleys).
Diameter of pulleys : 260 and 150 mm.
Velocity of belt : v = 13.6 m/s.
Preliminary tension : 25 kg/cm².
Effective pull : 8 kg/cm².
Air moisture : 57 % at 25° C.
(*a*) Belt on the pulley with its flesh side.
(*b*) Belt on the pulley with its hair side.

By measuring with a galvanometer the current i taken off the belt, and with the width of the belt, b, and its velocity, v, known, the density σ on any point of the belt can be calculated and put into relation to the highest possible density σ_{max}.

The distribution of the charges over the length of the belt.—Charges have not been found over the arc of contact of the belt with the pulley, no matter whether the pulley was of steel or of insulating material. The distribution of the charges is shown in Fig. 2, which is not symetrical because of the two different diameters of the driven and the driving pulleys. There is also a different density in the driving and on the driven side of the belt (a_1 and b_1) and the charges decrease for any side of the belt, if the charges are taken off its opposite side (a_2 and b_2), by which is proved that the charges are of the same polarity on both sides of the belt.

The influence of the speed of the belt.—The experiments confirm the theory that the current i increases in proportion to the increasing speed v of the belt, and that the density σ is not affected by this speed.

The effect of the preliminary belt tension.—The experiments show that the mentioned equations are not exact, and that also the conditions in the inner layers of the belt must be taken into account. As these conditions are determined to a great deal by the preliminary belt tension also the density σ is influenced thereby.

The influence of the effective pull.—In the case of no load both sides of the belt are subject to exactly the same stresses caused by the preliminary belt tension. In the case of load the stress in the driving side of the

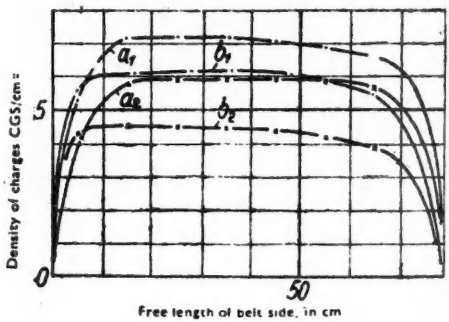


Fig. 2. Distribution of the charges on a belt.
Diameter of pulleys : 150 and 100 mm.
Velocity of belt : v = 10 m/s.
Preliminary tension : 53.4 kg/cm².
Effective pull : 38 kg/cm².
(a_1) Driving side of the belt.
(b_1) Driven side of the belt.
(a_2) Driving side of the belt, the driven side being electrically discharged.
(b_2) Driven side of the belt, the driving side being electrically discharged.

belt increases in proportion to the load. In the driven side the stress decreases. It should be expected according to what was said about the influence of the preliminary tension that the charge increases in the driving and decreases in the driven side of the belt. Yet this is not the case, and therefore the charges on the belt cannot be considered to originate by the pure elongation of the belt. The real cause of the charges is apparently the fact that the belt changes its length when passing from the driving to the driven side and simultaneously its radius of curvature, too, which results in an additional strain of flexure. This theory is confirmed, i.e., by measurements on leather belts laying with their flesh side or with their hair side on the pulleys. The belt is more compact on its hair side, and therefore it is subject to a lower strain of flexure if laying with this side on the pulley. Consequently, lower charges should be expected in this case than in the case it is laying on the pulley with its flesh side. The experiments confirm this assumption.

The relation between the density of the charge and the limit of the effective pull.—If the driven pulley has to overcome a resistance, the driving side of the belt is subject to an additional stress, whereas the stress of the driven side is reduced below the stress due to the preliminary belt tension. If the difference between the tensions in the two sides exceeds the value necessary for providing a sufficient pressure between the driven pulley and the belt the belt begins slipping. This point is the upper limit of the density σ for this case, and it further decreases with the load increasing.

Summarizing it can be said about electrostatical charges on driving belts :

(i) the charges are a function of the product of the speed v and the width b of the belt ;

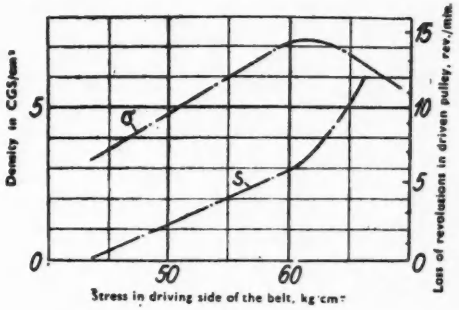


Fig. 3. Influence of elongation of belt, and of slip on the electrostatical charges.
Diameter of pulleys : 150 and 100 mm.
Velocity of belt : v = 10 m/s.
Preliminary tension : 40 kg/cm².
Up to about 60 kg/cm² stress the loss of revolutions of the driven pulley is due to the elongation of the belt, above this value there is an additional loss due to slip.

(ii) they increase if the preliminary belt tension is increased ;

(iii) they increase from a lower limit as determined by (i) and (ii) with the increasing load to an upper limit of $\sigma = 8$ electrostatical units

$$(C G S/cm^2) = .266 \times 10^{-8} \frac{\text{Amp.} \times \text{sec.}}{cm^2}$$

The experiments proved that no electrical charges are built up on endless woven belts, but in any case, on leather belts.

SURFACE COMPRESSION A MEANS OF INCREASING THE FATIGUE STRENGTH OF SPRINGS USED IN MOTOR VEHICLES

By O. FOEPPL. (From *ATZ, Automobiltechnische Zeitschrift*, Vol. 45, No. 12, June 25th, 1942, pp. 321-325).

SURFACE compression as a means of increasing fatigue strength was first carried out by the Woehler Institute, Braunschweig, in 1928. Although a number of publications appeared on this subject the method does still not receive as much practical consideration and application as it deserves by its merits. In this article some problems connected with surface compression are discussed with special consideration to the motor car industry, and the improvements obtainable by the application of this method briefly indicated.

Surface Compression of Valve Springs.

Surface compression is a particularly useful treatment for valve springs. Based on American experience all valve springs are treated in this way in Germany. Generally the patented process of the firm Roechling is used; this consists of a shot blast of steel balls directed against the surface to be treated.

The great advantage of surface compression was recognized in U.S.A. at an early stage (1930), before adequate attention was paid to it in Germany. So it happened that for some time German Industry had to depend on American machines produced for such treatment. Later experiments were carried out in the works of the firm Roechling, where tests appeared to indicate the fact that using a shot blast is more efficient than " hammering " the surface of the spring wire. However, later research work has proved that both systems are efficient as far as raising the fatigue strength of spring wire is concerned, provided the radii of the rounded head of the hammer and that of the balls used in the shot blast are the same. On the other hand, the shot blast method is much simpler, and can be applied to surfaces which are not readily accessible to the hammer.

In 1941 v. Manteuffel published results of research on surface compression. Manteuffel used in his experiments a sand blast and obtained improvement compared to shot blast. Frye and Kehl, reporting a similar research, did not agree with Manteuffel on the question of merits of sand. However, this might be due to the fact that Frye and Kehl used the same sand over and over again, which, due to impacting on the wire, was " ground " to a much finer sand ; Manteuffel used in his experiments fresh sand.

Valve-Springs Made of Surface Compressed Wire.

If valve springs are wound of ductile steel wire and are then hardened, it is often difficult to treat the wire surface with the steel-ball blast. In many instances, therefore, the springs are coiled from the already hardened steel wire and in this case it can be surface compressed before coiling. Experiments have shown great improvement in the fatigue strength of such springs, indicating that the wire can be coiled after surface treatment. Similarly for wire ropes it is suggested to use surface compressed steel if a high fatigue strength is essential.

The reason of the higher fatigue strength due to surface compression is not yet fully clarified. The author of this article believes that it is due to increasing the density of the surface layer, due to which the molecules are pressed closer together. The Woehler Institute and the Material Testing Institute of Darmstadt have carried out extensive research work on this line. Prof. Thum has hence conluded that the increased

fatigue strength is due to the residual stress in the surface layer which is caused by hammering or by the shot blast.

Experiments made by the author, however, indicate a third explanation to the phenomenon. The experiments were namely based on a surface compression method which does not increase the density of the surface layer, nor are residual stresses produced in the wire. It is a purely plastic deformation as illustrated in Fig. 1. A 2 mm. diam. ductile wire was used. The wire was pulled around two mutually perpendicular rollers (d and e) of 15 mm. diam. by a force P. Two wooden jaws (c) are used to keep the wire tight round the rollers. The wire is then straightened by three rollers (f, g and h), as shown in Fig. 1. The wire is bent at the points of contact with the rollers to a radius of 25 mms. The outer layer of the wire is thus elongated by about 8-10 %, and there is a corresponding compression of the inside fibres. At (b) the wire is again in its initial condition except for a 1.5% reduction of diameter, which corresponds to approximately 3% elongation of the wire length.

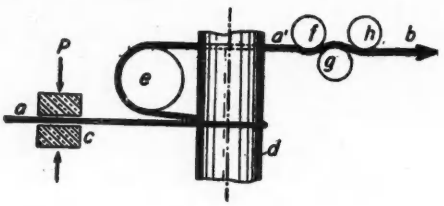


Fig. 1

Tensile strength measurements carried out on the wire show that this plastic deformation reduces the tenacity of the wire by about 6 %. Considering the reduction of cross section as mentioned above, the tenacity is still 3 % below its initial value.

The torsional fatigue strength of the wire has at the same time been increased by about 20%. In this case one cannot attribute the improvement in fatigue strength to the increase of density of the surface layer since the inside fibres are exposed to an effect opposite to that on the outside fibres. Similarly is the case regarding residual stresses.

As a matter of fact, only a reduction of fatigue strength could, if anything, be expected by these theories since the fatigue failure starts at the weakest point, which lies at the inside fibre at this case. The only possible explanation remains, therefore, that plastic deformation has produced a change of the molecular structure, increasing the fatigue strength of the material, while the tensile strength is somewhat reduced.

Experiments were restricted to hard steel redundant of over 200 kg/mm² strength and it is, therefore, not yet possible to state how the fatigue strength of softer wires will be affected by the plastic deformation described.

Hard wire has a high tensile strength and low notch-impact strength. The latter is, perhaps, the result of residual pre-stresses in the hard steel. These are relieved during plastic deformation and the notch-impact strength is thereby increased.

Torsion Bar Springs.

Experimental results on torsion bar springs have been published by Dr. Lippacher before. This type of spring, too, benefits greatly by surface compression treatment.

With these springs it was observed that the increase in fatigue strength was accompanied by a reduction of

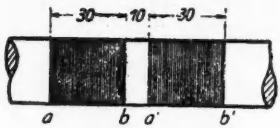


Fig. 2

the limit of elasticity, with the result that the spring slacks off sooner than an untreated spring. In effect the lowering of the elastic limit is tantamount to an increase in notch impact strength or a lowering of notch sensitivity. It is, therefore, imperative in the future to choose another steel for the manufacture of such springs; a harder steel can be selected.

This experience should be well considered in connection with other applications of surface compression. It is not sufficient to treat the article with a shot blast, but under certain dircumstances a different working material must be used.

The Woehler Institute has also carried out the following experiments :

A torsion bar (Fig. 2) was so treated that a section of 30 mm. length was surface compressed (a-b), the next part (b-a¹) of 10 mm. length was untreated, and then a length of 30 mm. was again surface compressed.

This partial treatment of the bar raised its fatigue strength but to a lesser extent as if it was fully treated.

Fig. 3 shows three rods after fracturing. In each case the failure starts in the untreated portion (marked by X) and except for the first rod the failure remained inside the untreated part of the rod. This shows the great influence of the surface treated neighbourhood on the conditions of fatigue failure.

Experiments were also carried out on a hard cylinder (160 kg/cm² strength) of a Rockwell C hardness of 50.2. After treatment in a manner described above, the surface compressed portion had a hardness of 51.8 while the hardness of the untreated portion was raised by 0.4 Rockwell C units. This increase in hardness may be attributed to the effect of compressive stresses in a- due to surface compression of the nei hbouring sections.

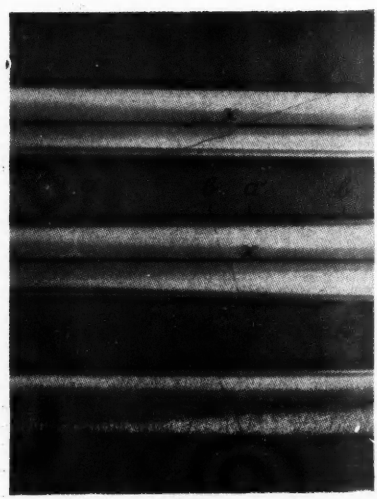


Fig. 3

TURBO-COMPRESSORS IN THE METALLURGICAL INDUSTRY

By F. KLUGE, Duisburg. (From *Stahl und Eisen*, Vol. 62, Nos. 28 and 29, 9th and 16th July, 1942, pp. 588-591 and 608-612).

Design of Turbo-Compressors. Modern Units.

General lay-out and number of stages.—The general lay-out of turbo-compressors is governed by the required suction volume as well as by the delivery pressure; the first being important mainly for the choice of the speed and the diameters of the impeller wheels and for the choice between single and double suction type, and the latter being decisive for the number of stages. As the same delivery pressure can be obtained with a certain number of impeller wheels running at a given speed as well as with a smaller number of impellers running at an accordingly higher speed, the number of stages is also a function of the speed chosen for the impellers.

During recent years the number of stages could be considerably reduced thanks to the improved properties of the materials which made higher peripheral velocities possible. Using Chromium-Nickel-Molybdenum-steel of high mechanical properties, the Demag Works succeeded in building two-stage compressors with a pressure ratio of 2.2 to 2.4 for which formerly four stages were necessary. Fig. 1 shows a cross sectional view of this turbo-compressor for a suction volume of 45,000 to 60,000 m³/h and a pressure ratio of 2.2 to 2.4 at full load and up to 2.6 at partial load. This turbo-compressor is driven by a steam turbine with speed regulation, which insures an efficient regulation of the turbo-compressor over its whole operating range. The rated peripheral velocity of the impellers is 280 m/s, the maximum velocity is 300 m/s. Thanks to its high peripheral velocity and to its layout as only a two-stage unit, this turbo-compressor requires the smallest possible space.

Up to pressures of 6 to 7 meters water column, single stage compressors can be used. A compressor of this type and of the Volute type, rated for a volume of suction air of 40,000 m³/h at 1 atm. and a delivery pressure of 1.7 atm. is shown in Fig. 2.

In Germany, through Government restrictions concerning the use of Nickel, Chromium and Molybdenum, the development towards higher speeds is impeded, but a quick development in this direction is expected for the post-war years.

Construction of Impeller Wheels.—Both discs of the impeller wheels are usually of forged steel. The blades are curved, their outlet-angle being between 40° and 50°. They are cold hammered into Z-shaped cross-section and fixed to the disc by steel rivets with countersunk heads, as shown in Fig. 3 (Demag Works and others). Brown-Boveri uses blades with rivets machined out of the solid, the reinforced rim giving the rivets good support.

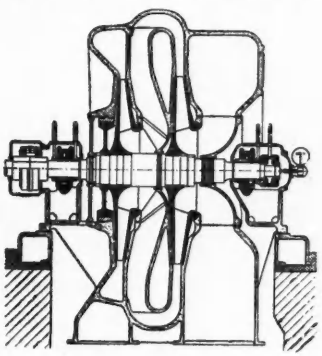


Fig. 1

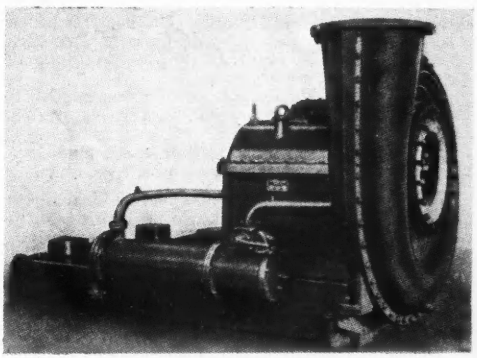


Fig. 2

Every impeller wheel is tested at overspeed and dynamically balanced before being built in. The impellers can be fixed to the shaft by shrinking. Distance rings are put between them, and keys prevents them from turning on the shaft.

Casings.—The casings for turbo-compressors must be as simple in design as possible. Size and shape are determined by the required volume of suction air. At present single-inlet compressors are being built for suction volumes up to 100,000 or 120,000 m³/h. If designed for larger volumes, the diameter of the impellers would become so large that the limited strength of the material would require a lower speed. This in turn would mean larger dimensions and higher cost of the compressor. Consequently, turbo-compressors for suction volumes exceeding the said limit are always of the double-inlet type. This type possesses the additional great advantage of being in axial balance, whereas the tendency of the single-inlet impeller to move towards the suction end must be counteracted by

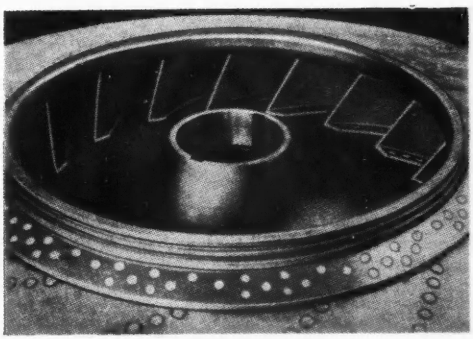


Fig. 3

special pressure pistons, which complicate the design and construction of the compressor. However, a special thrust bearing to cope with occasional thrusts in axial direction is necessary in either case.

There is no cooling provided for compressors serving blast-furnaces, though the end temperature of the compressed air may reach 150° to 200° C. The main reason for the absence of a cooling system is that the construction of the compressor would become unnecessarily complicated, and that the air must be in any case preheated up to 600° to 900° C. before being supplied into the blast furnace. The compressed air arriving at 150° to 200° C. at the air heater, the blast furnace gas otherwise necessary for pre-heating the air up to this temperature is saved.

Huge casings usually consist of several parts to simplify the castings and manufacture. Yet certain firms still prefer horizontally divided casings consisting of only two parts—base and cover—with guide and return rings cast into one piece even for huge units.

Guide Blades and Diffuser.—The air leaves the impeller wheel at a high outlet velocity which must be transformed completely into pressure energy if a high efficiency is to be obtained. For this purpose serve the sometimes adjustable and sometimes rigidly fixed guide blades or the bladeless diffusers. Brown-Boveri use both rigidly fixed and adjustable blades, the first being definitely adjusted only after the trial running of the compressor has interplan with the corresponding blast furnace under normal working conditions. By means of the adjustable guide blades, on the other hand, the compressor can be easily adapted to the operational changes occuring in the blast furnace, like change of quality of iron ore or coal, change of daily output, holidays, etc., so that the surging can be avoided over a very wide range of volume.

Other firms avoid the additional regulating devices required for adjustable blades and prefer obtaining the same results by adequately designed blades or diffusers only. The characteristics of a turbo-compressor of this second type, manufactured by the Demag Works, Germany, are shown in Fig. 4. This compressor handles any suction volume from 25,000 m³/h up to

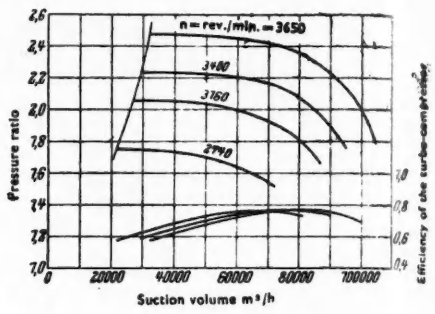


Fig. 4

100,000 m³/h without surging, and with a delivery pressure of 2 atm.

Weight and Space required.—By increasing the speed and peripheral velocity, and consequently by using fewer stages for the same suction volume and the same pressure ratio, the weight and space of turbo-compressors has been considerably reduced. For instance, the specific weight of a large turbo-compressor for 2 atm. delivery pressure, built in 1930, was 0.38 kg/m³/h, and the specific space 0.3 m²/1,000 m³/h. For a compressor of the same output, built in recent years the corresponding figures are 0.15 kg/m³/h and 0.16 m²/1,000m³/h. At the same time the peripheral velocity was increased from 190m/s in 1930 to 300m/s.

Thermal Characteristics of Turbo-Compressors.

The economy of a turbo-compressor depends mainly on its load, the highest efficiency being reached at full load. At overload or partial load the efficiency factor decreases. In huge units with a suction pressure of 1 atm. and a delivery pressure of 2.2 atm. as usually required for blast furnaces, the efficiency may reach up

TABLE I. Heat consumption of a Turbo-compressor.

Volume of suction air	Q_s	m³/h	75,000	100,000	150,000	190,000
Suction pressure	P_s	atm.	1.0	1.0	1.0	1.0
Temperature of suction air	t_s	°C	20	20	20	20
Delivery pressure	P_D	atm.	2.2	2.2	2.2	2.2
Efficiency factor of Turbo-compressor	η_{ad}	%	69	75	76	74
Power input at coupling	N	HP	3,560	4,370	6,470	8,420
Pressure of live-steam	P_e	atm.	13	13	13	13
Temperature of live-steam	t_e	°C	350	350	350	350
Temperature of cooling water	t_w	°C	27	27	27	27
Vacuum	P_o	atm.	0.06	0.065	0.07	0.08
Efficiency factor of steam turbine	η	%	73.5	76.5	80	77
Steam consumption	D	kg/h	13,600	16,210	23,230	32,000
Steam consumption as above, but with allowance for auxiliary motors, etc.	D'	kg/h	13,950	16,630	23,800	32,800
Specific steam consumption	d'	kg/m³air	0.186	0.1663	0.1589	0.1728
Efficiency of boiler	η_k	%	82	82	82	82
Heat consumption $Q' = \frac{D'(i_1 - t_k)}{\eta_k} 10^6$	Q'	kcal/h	12.19	14.5	20.72	28.42
Specific heat consumption $q' = Q'/Q_s$	q'	kcal/m³air	162.3	145	138.2	149.7
Useful heat contained in the compressed air from a turbo-compressor $q'' = \frac{Q_s \gamma_s C_p (t_{Dad})\, 0.85}{Q_s}$	q''	kcal/m³air	7.16	5.25	4.89	5.6
Specific heat consumption of a turbo-compressor after deduction of useful heat contained in the compressed air, i.e., for the compressed air containing the same amount of heat as if it came from a reciprocating compressor $q = q' - q''$	q	kcal/m³air	155.1	139.8	133.3	144.1

to 78%, the adiabetic compression being considered 100%. The following investigations are based on the assumption that the thermal efficiency of a 150,000 m³/h turbo-compressor, pressure ratio 2.2, is 76% for full load(adiabet. compression = 100%), 74% for 25% overload, 75% for two-third load, and 69% for half load, which values are normally reached by units of this sort.

Owing to its very similar working process and design, the steam turbine is a very suitable driving machine for the turbo-compressor. The possibility of varying the speed of the set without losses allows of adjusting the operation of the turbo-compressor to the requirements of the furnace being supplied. Therefore, in the following only the steam turbine is taken into consideration as prime mover. The highest efficiency of the steam turbine being reached if working at full load and with the efficiency decreasing with increasing or decreasing load, similar to the efficiency of the turbo-compressor, both machines will be rated so as to reach their highest efficiency simultaneously.

Yet, the efficiency at any load of the turbine, besides being determined by its construction, is also a function of the pressure and the termperature of the live-steam, and by the temperature of the cooling water for its condenser. With a live-stream pressure of 13 atm., temperature 350° C., and with a vacuum of 0.07 atm. corresponding to water of 27° C., a highest efficiency of 80% for full load can be reached. Accordingly, 77% efficiency was calculated for the highest obtainable overload (194,000 m³/h), 76, 5% for two-thirds of the full load, and 73% for half load (Table 1). From these values the steam consumption D was calculated. An allowance of 2½% for auxiliary machines increases the steam consumption to D kg/h. From this in turn follows the specific steam consumption d per kg/m³ of suction air.

If the heat economy of a steam turbine driven turbo-compressor is to be compared with the economy of a gas engine driven reciprocating compressor, the boiler necessary to supply the steam for the turbine must be taken into account, as it constitutes an energy loss which does not occur if a gas engine is used, where the energy contained in the furnace gas is immediately transformed into mechanical energy. With an anticipated total efficiency of 82% for the boiler the specific heat consumption q kcal/m³ of suction air, of the complete plant consisting of boiler, steam turbine, turbo-compressor and auxiliary machines, equals q = 138.2 kcal/m³ for full load. It becomes 149.5 for the highest overload, and 162.3 for half load.

It further must be taken into account that due to the higher internal losses if compared with the reciprocating compressor, the compressed air when leaving the turbo-compressor is of a higher temperature than the compressed air supplied by a reciprocating compressor under the same working conditions. This heat, however, is not a loss, as already pointed out before, if the compressed air is used in a blast furnace, because the air has to be preheated still further before being supplied to the furnace. Therefore, the amount of heat contained in the compressed air coming from the turbo-compressor exceeding the amount contained in the compressed air supplied by a reciprocating compressor working under the same conditions, must be deducted from the total energy consumption of the turbo unit, if an exact comparison of both systems is required.

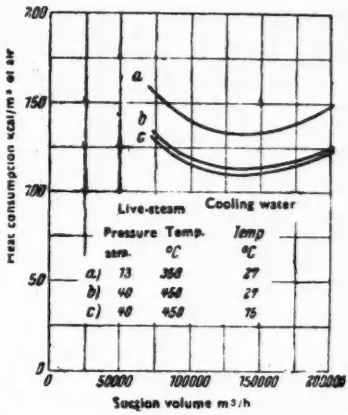


Fig. 5

For the above example the final energy consumption after deduction of the heat utilized in the blast furnace, is: 133 kcal/m³ suction air for the rated output (full load), 144.1 kgal/m³ suction air for the highest possible output, and 155.1 kcal/m³ suction air for half load. These figures can be further improved by using a condenser cooled by fresh water instead of a condenser with limited water supply and cooling pond, as was assumed for this example.

Fig. 5 shows how the heat consumption of a steam turbine-driven turbo-compressor can be reduced through increasing the pressure and the temperature of the live steam. It must be pointed out that the figures of heat consumption, efficiency, etc., as given in the above example are not figures obtainable merely during short test runnings, but figures which ought to be reached during normal operation of similar units.

THE USE OF THE CUPOLA FURNACE FOR METALLURGICAL PURPOSES IN THE MELTING OF CAST IRON

By HERMANN KOPP, Esslingen. (From *Die Giesserei*, Vol. 29, No. 14, July, 1942, pp. 237-243).

THE cupola furnace is not only a melting furnace but may control qualities of the melted iron. Different types of furnaces. Influence of charge. Three types of melting methods.

The cupola furnace is the simplest form of melting plant in the grey iron industry; and since it is extremely economical and easy to manipulate its use has become almost universal.

It is frequently regarded only as a means of effecting a simple re-melting of cast iron. In point of fact it is possible to influence the qualities of the iron both by different methods of furnace design and by the type of coke chosen.

The cupola furnace may be used for any one of the following purposes, each requiring an independent technique.

1. To produce without intentional alteration in the composition of the material, a simple remelt. For this purpose a mixture of crude iron and cast scrap is used, and the result is a cast iron of medium quality. The carbon content of this iron is not important.
2. To obtain a cast iron of low carbon content and very high tenacity. This necessitates the addition of a certain amount of steel scrap to the mixture of input ores. Complete control of the furnace is essential for the maintenance of a constant carbon content.

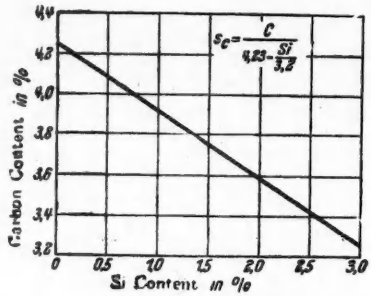


Fig. 1. Saturation of carbon content as influence by silicon content.

3. To produce an iron whose carbon content is higher than that of the metal charged.

These products and the methods used for obtaining them, may now be considered in detail.

1. The simple remelt is often regarded as identical in composition with the input material. This is not entirely true. Many chemical reactions occur between the melt and the fuel, the products of combustion and the slag, all of which influence to some extent the end product.

The quality of the cast iron will naturally depend largely on the choice of the metal charged. It is, however, affected by other factors, some of which are readily controllable.

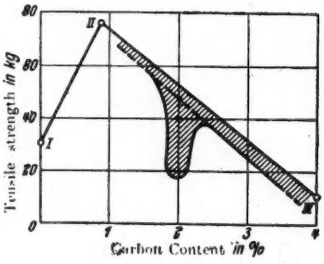
It has not yet been found possible to effect a complete removal of phosphorus.

The silica content can be regulated without much difficulty by the addition of appropriate chemicals to the melt. In conjunction with the use of reagents for de-sulphurising a fore-hearth is recommended, in order to give opportunity for complete separation of the liquid iron with its basic slag from the acid furnace slag. De-sulphurisation may, however, often be effected solely by the addition of a sufficient quantity of lime to the melt. Observation shows that the amount required to keep the sulphur below 0.1% is 25-30% of the amount of coke used. The exact quantity needed will also depend on the composition of the charge.

There is a widespread belief that large amounts of lime attack the furnace linings, but investigation has shown that the addition of as much as 50% lime has no deleterious effect.

Fig. 2

Influence on tensile strength in grey cast iron of change from 1.8% to 2.2% carbon which induces a change in the form of the graphite.



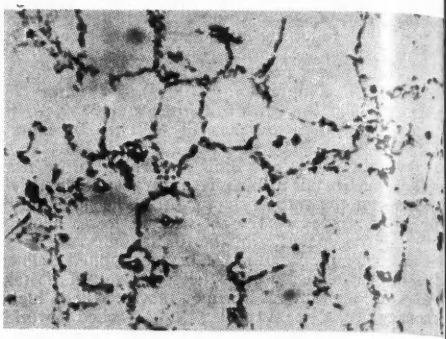


Fig 3. Unfavourable influence of the form of the graphite in low carbon cast iron.

It is known that there are definite losses of silica and manganese in the melting process.

The carbon content of this cast iron is of no great importance. It tends to approach the carbon saturation point, which varies with the silica content of the melt (Fig. 1). To obtain a high carbon content, e.g., for chill cast cylinders, Krupps have substituted pitch coke (a constituent of coal tar) for ordinary melting coke.

2. To obtain a metal of high tenacity the melt must contain a proportion of scrap steel (0.2-0.4% carbon). For some time it was considered dangerous to include more than 20% of this material, but modern methods successfully incorporate 50-80%.

It is essential that the carbon content should not exceed 2.4%. Melted iron particularly when low in carbon, greedily absorbs this element from the glowing furnace coke, especially at high temperature. Contact with the coke must therefore be minimised or preferably eliminated by the use of a fore-hearth.

The tenacity of a cast iron does not increase indefinitely in inverse proportion to its carbon content; below a figure of approximately 2.4% the tenacity value tends to decrease (Fig. 2).

The reason for this decrease in tenacity is that the graphite, instead of having an even distribution, occurs in the form of a network, which is very detrimental to metallic cohesion (Fig. 3).

3. When iron smelting is done in conjunction with a machine factory it is often economically advisable to use very large amounts of scrap steel. In these cases it may be necessary to increase the carbon content deliberately in order to avoid the falling off of tenacity which occurs below the 2.4% limit. In these circumstances the fore-hearth with low blast pipes should not be used.

Enriching of the liquid iron by carbon should be ensured by subjecting it to contract with large quantities of coke at high temperature for as long a period as necessary.

From this short survey it will be seen that the cupola furnace has many possibilities. By competent choice of materials, slags and cokes, combined with careful designing of the furnace and adequate control of conditions, a great variety of products can be obtained—products, moreover, of a predictable standard, whose qualities can be guaranteed and maintained.

CEMENT as a MATERIAL for the CONSTRUCTION of CASTING MOULDS

By HANS GOEDEL, Chemnitz. (From *Die Giesserei*, Vol. 29, No. 14, July, 1942, pp. 249-250).

THIS practice has recently attracted considerable interest, owing to its obvious economic and technical advantages. It has been used in many types of foundry both in Germany and other countries.

Cement moulds can be used for a large range of metals, including cast iron, cast steel, magnesium, magnesium alloys, bronze, etc. Their construction does not depend on the availability of any particular

variety of sand, and any type of mould can be made. They are also extremely economical of metal, fuel and wages.

The following figures show some of the advantages of this method of casting. They are taken from a factory employing 180 men and casting 5,000 tons of iron per year.

Decrease in moulding time	20%
Saving of core oil per annum ..	5,000 kg
Saving of iron for moulds	250 tons
Saving of fuel per month	80 tons
Saving of new sand	60-160 tons, etc.

The making of cement moulds and cores for iron and other casting metals is so simple that only unskilled labour need to be used. They are made from a mortar-like mixture, usually of cement and sand bound with a quantity of water insufficient for complete hydration.

From this mixture moulds and cores can be formed with very little pressure—often in fact, by shaping with the fingers.

These moulds are not subject to contraction, they are self-supporting and easily transferable with little danger of breakage. They can be used shortly after making and do not require artificial drying.

If desired the moulds may be furnished with a facing lining. The water from this is immediately absorbed by the cement, owing to the incompletely hydrated condition of the latter.

Cement moulds are porous, and any gas contained in the casting metal can diffuse away through their walls. This ensures that the castings will contain no gas blisters and also eliminates the possibility of explosions caused by trapped gas.

The moulds and cores give only slight resistance to shrinking of the casting metal. Separation from the cast is very easily effected by shattering the mould with a slight tap.

A typical example of the constitution of these moulds is as follows :

100 volume finely ground Portland cement
600 volumes sand
90 volumes water.

Moulds and cores are given a facing of pulverised graphite in aluminium cement milk.

A PHOTO-MAGNETIC DEFECTOSCOPE

By M. M. SLIOZBERG, Siberian Metallurgical Institute, Division for Energetics. (From *Zavodskaja Laboratoria*, Moscow, Vol. 10, No. 3, March, 1941, pp. 279-281).

DEFECTOSCOPES are instruments for detecting defects in magnetic materials by observing the variation of their permeability. This instrument converts the variations in permeability into variations of luminous flux, and thus into variations of a D.C. current.

The apparatus was described in a report published by the author of this article in the journal for Technical Physics, issued 18–19, 1937. (Electro-optical Method of Measuring Alternating Voltages and Currents by Photo-elements).

The simplified diagram of this apparatus is shown in Fig. 1. The alternating current (J~), produced by an alternating magnetic flux, produces, through the transformer Tp, a certain glow of the filament of the Photometric Lamp L. The light flux of this lamp is directed on the photo element $\phi 3$ (a selenium photo element) by an optical system and produces there a D.C. e.m.f. responding immediately to the smallest change in the intensity of the alternating current. This e.m.f. in turn produces a corresponding current $J\lambda$ through the coil of the galvanometer.

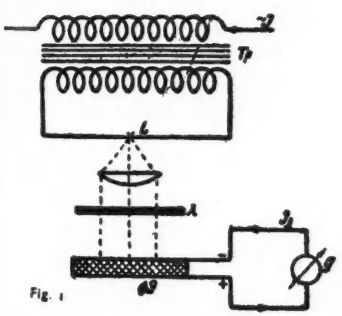


Fig. 1

The relation between the intensity of the radiation of the filament $E\lambda$ and its temperature T is given by Planck's equation

$$E\lambda = C_1 \lambda^{-5} \frac{1}{e^{\frac{C_2}{C\lambda T}} - 1}$$

where C_1 and C_2 are constants, λ the wave length and T the absolute temperature. It is evident that a small increase in temperature results in a sharp increase of $E\lambda^2$, and it is only this fact which makes the method so highly valuable for measuring alternating currents. A very small increase in the current which heats the filament the intensity of the radiation responds with a sharp increase, and consequently so does the intensity of the photo-current. The experimental values (Table 1) show the exponential character of the direct current J as a function of the applied alternating voltage U_V. In other words, they show the great sensitivity of this method for measuring small changes in alternating voltages and currents.

In compiling the figures as in Table 1, the author used the whole flux of light of a 4-volt bulb, a photo-element of the type LETI with an active surface of 20mm² and a sensitivity of 420 milliampere per lumen, and a galvanometer with a sensitivity of $1° = 0.25\ 10^6$ amp. The galvanometer has a scale of 100 degrees. Various resistances were used in the course of the experiment, and the figures of Table 1 are readings already brought to a common base.

The diagram (Fig. 2) differs from the diagram in Fig. 1 only by an additional battery B (2–4 volts) which makes the lamp, L, glow even if the e.m.f. induced by

TABLE 1.

$J\lambda = f(U\sim)$

U volts	$J\lambda$ in degrees of the scale	U volts	$J\lambda$ in degrees of the scale	U volts	$J\lambda$ in degrees of the scale
1.0	5.3	2.1	253	3.1	1110
1.1	9.5	2.2	312	3.2	1245
1.2	16.0	2.3	375	3.3	1380
1.3	24.0	2.4	442	3.4	1520
1.4	36.0	2.5	510	3.5	1665
1.5	51.5	2.6	580	3.6	1815
1.6	69.5	2.7	670	3.7	1970
1.7	96.0	2.8	765	3.8	2130
1.8	125.0	2.9	865	3.9	2310
1.9	160.0	3.0	980	4.0	2510
2.0	205	—	—	4.1	2730

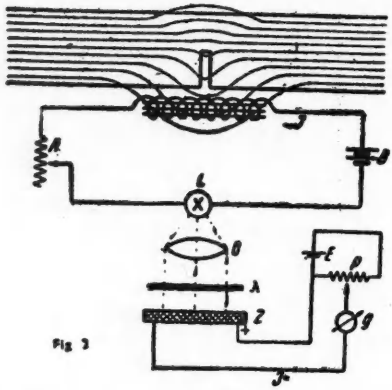


Fig. 3

the dispersion of the magnetic field is not strong enough. As it is desirable to have the pointer of the galvanometer at zero until the " defect finder " (the induction coil) is brought on to the work piece, another battery E is added, and the photo-current can be compensated through the potentiometer P. The same potentiometer serves also to compensate to a high degree the influence of the general magnetic background on the " defect finder " running round the rough surface of the work piece.

In Fig. 3 a more exact and more sensitive scheme is added, which eliminates all the errors arising from the magnetic background, from changes in the voltages of the electricity supply, from changing conditions in the photo-element itself, etc. It is a differential apparatus and consists of two exactly similar and symmetrical parts, both of them containing an induction coil. One coil is used as a standard and is put on to a sound part of the work piece, the other coil is the " defect finder " and is moved along to the work piece. To increase the sensitivity the photo elements $\phi 3$ and $\phi 3_2$ are short-circuited by the galvanometer. A still higher sensitivity can be reached by replacing this system by a " photologometric " system which show the direct relation between the two photo-currents, and thereby eliminates a number of minor operational difficulties (article by M. M. SLIOZBERG, " *The Logometrical Method of Photoelectrical Measurements*," *Journal of Technical Physics*, *Vol.* 22, 1937).

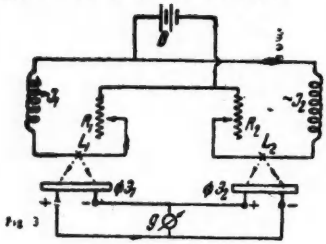
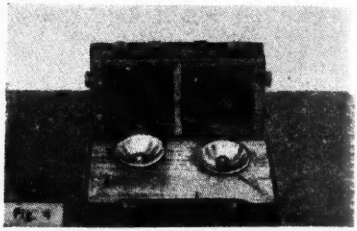


Fig. 3



The appearance of the double system " photo indicator of electrical currents," with its two photo-elements and two lamps can be judged from Fig. 4 (size of the box $150 \times 60 \times 80$ mm.). With the capacity of the photometric lamp limited a small ohmic resistance of 2-3 ohm must be inserted in the circuits of both induction coils.

An experimental set was built for investigation of rails by this method.

The diagram, Fig. 5, shows clearly two different curves representing the intensity of the direct current passing through the galvanometer in function of the alternating current applied for the magnetization of the rail. One of these curves (full line) represents measuring on a sound part of the rail, the other (dotted line) measuring on a defective part. The distance between the two lines is essential as it is a good measure of the sensitivity of the apparatus, and depends on both the current of the circular magnetization of the rail, and the additional voltage U bat of the lamp. As shown in Fig. 5 the increase of U_1 bat $= 0.4$ volts to U_2 bat $= 0.42$ volts, i.e., of only 0.02 volts results in a much higher sensitivity of the apparatus. As then, low additional voltages used in this particular experiment were by far not enough to produce a full glow of the filament, it is evident that the sensitivity obtained in this case is below the sensitivity obtainable with this apparatus.

The defects found by this apparatus include zones of accumulations of non-metallic inclosures as well as of deficiency of Pearlite which may extend to a depth of 3 mm. from the surface of the base of the rail.

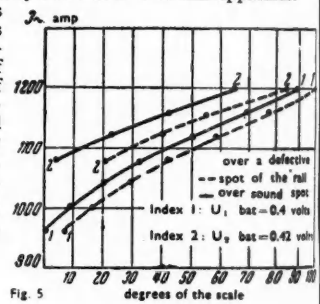


Fig. 5

FLUORESCENT LAMPS IN THE U.S.A.

By HEINZ HAUSNER, New York. From *Bulletin Association Suisse des Electriciens*, Vol. XXXII., No. 15, 30th July, 1941, pp. 354-55).

THE reason for the wide use of fluorescent lamps is that they enable different colours, including daylight colours, to be produced with very high efficiency. Lamps of various ratings are manufactured in the U.S.A., photometric details for some of which are given in Table 1. It will be seen that efficiencies of the order of 50 L/W for the white and daylight colours are possible. For the 30 W. green colour the efficiency is 75 L/W.

TABLE 1.

Lamp Watts	15	20	30	40	100
Length (inches)	18	24	36	48	60
COLOUR.			Lumens.		
Daylight	525	760	1,300	1,800	3,700
White	585	860	1,450	2,100	4,200
Blue	315	460	780	—	—
Green	900	1,300	2,250	—	—
Pink	300	440	750	—	—
Golden	375	540	930	—	—
Red	45	60	120	—	—

Table 2 gives some technical data for these lamps, and Table 3 gives details about the luminescent materials used.

TABLE 2.

FLUORESCENT LAMP TYPES IN THE U.S.A.					
Lamp Watts ..	15	20	30	40	100
Diameter (inch) ..	1	1.5	1	1.5	2.1/8
Length (inches) ..	18	24	36	48	60
Nominal lamp current A.	0.30	0.35	0.33	0.42	1.45
Nominal lamp voltage V.	56	62	103	108	72
Supply voltage V. ..	110/25	110/25	200/20	200/20	200/20
			220/50	220/50	220/50
			110/25	110/25	110/25
Life hours	2,500	2,500	2,500	2,500	3,000

The low-pressure mercury discharge produces little visible radiation itself, but very intense UV radiation. A great deal of this UV radiation is converted into coloured light by the luminescent powder coating on the inside walls of the tube. Fig. 1 shows diagrammatically the conversion of radiant energy into light as performed in one of the new lamps. Of course, the luminous efficiency depends upon the colour of the light (Table 1).

TABLE 3.

Flourescent materials, their excitation and their radiation.

Material	Colour	Excitation Wave Length a maximum at	Radiation Wave Length a maximum at
Calcium-Tungstate	Blue.. ..	2,730	4,400
Magnesium-Tungstate	Blue-White..	2,850	4,800
Zinc-Silicate ..	Green ..	2,537	5,250
Zinc-Beryllium-Silicate	Yellow-White	2,537	5,950
Cadmium-Silicate ..	Yellow-Pink	2,400	5,950
Cadmium-Borate ..	Pink ..	2,500	6,150

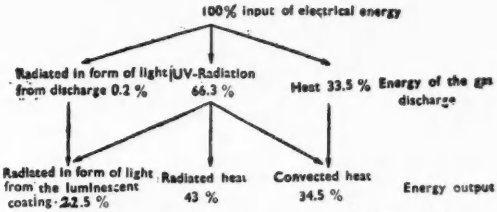

100% input of electrical energy
Radiated in form of light from discharge 0.2 %
UV-Radiation 66.3 %
Heat 33.5 %
Energy of the gas discharge
Radiated in form of light from the luminescent coating 22.5 %
Radiated heat 43 %
Convected heat 34.5 %
Energy output

Fig. 1 Conversion of energy in a typical low pressure mercury vapour fluorescent lamp

It can be seen from Table 2, that the lamps, unlike the usual incandescent lamps, have a considerable length of about 18 to 60 inches. But these unusual dimensions are not causing any difficulties, even with regard to residential use, as suitable fittings are now available. Among the various types of lamps, 15 watt daylight lamps are generally chosen for the illumination of tables, the 100 watt tubular lamp of 60 in. length is used for lighting large areas such as workshops and drawing offices. The majority of lamps in use have an input of between 15 and 40 watts, and are of white or daylight colour. The number of lamps of other colours is very small (5–10%).

The rapid increase in the use of fluorescent lamps has been supported by an effective propaganda and by a considerable increase of life and efficiency during recent years, and by a decrease of the price shown by the following figures :—

		1939.	1940.
Lamp Price ..	..	$ 2.80	2.30
Life of the Lamps	..(hours)	1,500	2,500
Luminous Flux ..	(lumen)	1,400	2,120

NEW DEVICES FOR HOLDING THE MATERIAL IN ELECTRIC BUTT- AND FLASH-WELDERS

By DIPL. ING. PAUL FLORIAN, Berlin. (From *Werkstatt und Betrieb*, Vol. 75, No. 6, June, 1942, pp. 129-130).

IN recent years considerable developments have taken place in automatic flash-welding. This system is now widely used for the mass production of a great variety of products. The principle of automatic flash welding is such that the parts to be welded when clamped in position are maintained in light contact, and when the current is switched on an intense heat is rapidly developed at the point of high contact resistance by the passage of heavy current at low voltage. After the welding temperature is reached, the current is switched off automatically or by hand, and the requisite forging or upsetting pressure applied.

The jaws of the welder must clamp the material in position by a pressure exceeding the upsetting pressure by approximately 50%. In addition, they must transmit to the material the total electrical energy required for welding and must, in certain cases, carry off the excess heat generated during the welding operation. For the latter reason they sometimes are water cooled. They must be made of a material possessing both a high electrical and heat conductivity. For the above reason the jaws, which are in most cases interchangeable, are of electrolytical copper or of certain copper alloys, and only in exceptional cases of other material. The necessity to have the work perfectly clamped in position is obvious by the fact that the welding current may be up to 100,000 A for large and several thousand Amperes for small sets. If the pressure by which the work is

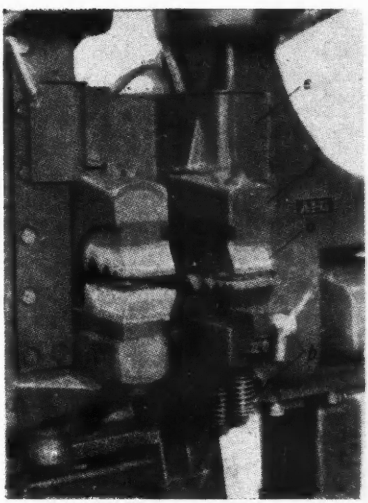


Fig. 1. Jaws of a hand operated butt welding machine with 5 V-shaped groovesfor holding fast round bars of different diameters.

a jaw with V-shaped grooves.

b device for vertical adjusting of the right lower jaw.

c covers for protection of the welding transformer.

d upper jaw support.

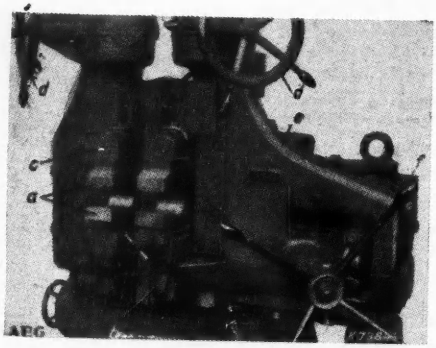


Fig. 2. Butt-welder adapted for welding thin walled tubes. The jaws with round grooves insure the passage of the welding current over the whole surface inside the jaws.
a jaws for clamping the tubes
b device for vertical adjusting of the right lower jaw
c support of welding jaw "a," moving vertically
d hand wheels for operating the upper jaws
e slide for horizontal movement
f handle to operate slide "e."

held is not high enough, or if other faults occur, damage caused to both the work and the jaws may be the result. To avoid this the jaws must be of adequate shape or special devices must be fixed to the ordinary jaws of the welder in certain cases.

As a rule butt and flash welders are delivered with plain and even jaws, which are suitable to hold work pieces of a great variety of shapes and a great number of differently fashioned bar iron. The easy passage of the electric current is safeguarded by a high clamping pressure which keeps the resistance low at the points of contact. In the case of round bars, e.g., drills or thick walled tubes, jaws with V-shaped grooves prove satisfactory. (Fig. 1). For thin walled tubes round grooves insure the passage of the welding current over almost the whole circumference of the tube, which is not deformed by the clamping pressure as would be the case if V-

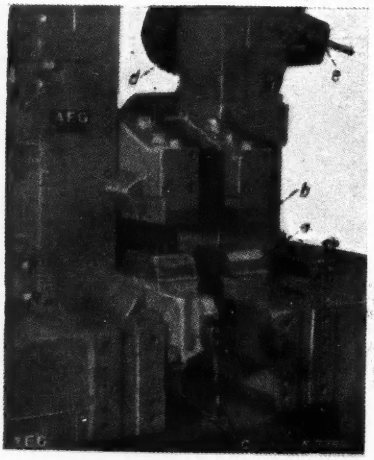


Fig. 3. Automatic butt-welder adapted for welding rail sleepers.
a lower jaw fashioned according to the rail sleeper
b upper jaw, with plain and even surface
c device for vertical adjusting of the left lower jaw
d motor for the control of the right upper jaw
e motor reversing switch.

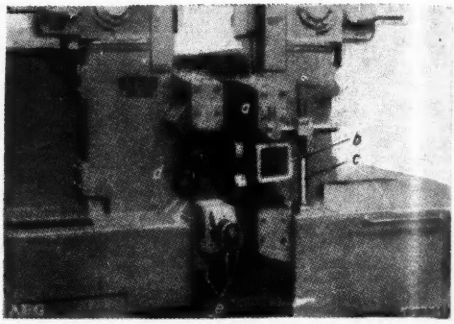


Fig. 4. Welder adapted for fixing high speed steel tips to tools.
a revolving hexagonal tool holder
b frame to avoid displacement of tool during the welding
c adjustable support for the frame "b"
d copper jaws holding fast the high speed steel
e device for vertical adjusting of the left lower jaw.

shaped grooves were used. For different diameters of the pipes different jaws should be used. To avoid this filling parts may be used with jaws designed for the biggest required diameter. These parts which mostly are of copper, have the shape of a pipe cut lengthwise in half, the outer diameter corresponding to the groove in the jaw, and the inner diameter corresponding to the outer diameter of the work. The filling part must fit exactly into the jaw. They can not be water-cooled. For welding rail sleepers the lower jaws must be specially shaped. In many cases when the mere fashioning of the jaws is not sufficient to insure perfect welding conditions, special devices must be developed for clamping the work. Fig. 4 shows such a device developed for flash welding of high speed steel tips to the tools for use on lathes, planers, shaping machines, etc. The difference in the specific electrical resistance of the high speed steel and of the steel to which it is to be welded, is compensated by the materials of the respective special jaws. These special jaws are held fast by the ordinary jaws of the welder. The jaws holding the high speed steel, which is of higher specific resistance, are of copper, those holding the tool are of steel and clamped by steel bolts to the ordinary jaws. The hexagonal tool holder being revolving, the tool must be passed through the frame "b" (Fig. 4) before being fixed. This frame can be freely adjusted, and its purpose is to prevent the tool from turning round while the welding process is in progress. The high speed steel tip is held by two copper jaws and simultaneously pressed to a copper back plate, which facilitates the passage of the welding current.

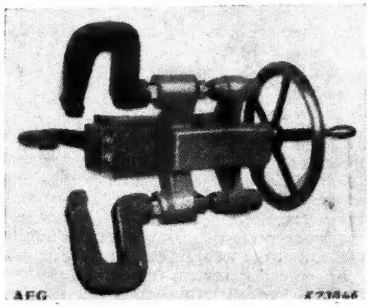


Fig. 5. Special holdfast for buffer discs, for use with normally shaped jaws.

For the welding of buffer discs to their rods a special device was developed as the discs can not be perfectly held by specially shaped jaws only. Fig. 5 shows the holdfast specially designed for this purpose, which itself is clamped between the two ordinary plain and even jaws of the welder. The buffer rod is held fast by ordinary V-shaped jaws.

Another device worth mentioning serves to adjust accurately the materials in respect to one another. This device enables one of the two lower jaws of the welder to be raised or lowered a few millimeters. This proves an advantage if the drills or pipes to be welded are held fast by the jaws where they are not machined, in which case slight irregularities may occur which this device serves to eliminate. Fig. 1 and 2 show this device fixed to the right lower jaw, and Figs. 3 and 4 to the left lower jaw of the welder.

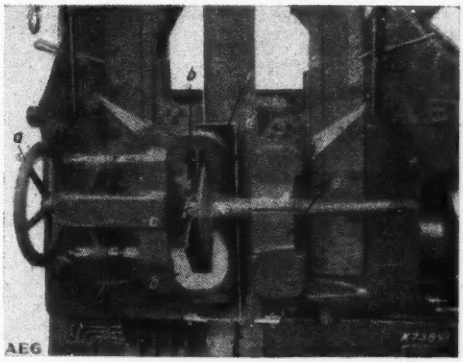


Fig. 6. Welding the rod to the buffer disc.
a Handwheel of holdfast for the disc. *b* Claws of the holdfast for the disc. *c* Water cooled copper bloc. *d* Welded joint. *e* Jaws with V-shaped groove for the rod. *f* Cover for the welding transformer

AUTOMATIC DEVICES AID STAMPING AND PRESSING

By E. VERGEN, VDI, Berlin. (From *Maschinenbau* (*Der Betrieb*), Vol. 21, No. 5, May, 1942, pp. 185-190).

Material used for Stamping and Forming.

DIFFERENT properties are required in materials subject to stamping and forming than in those being machined. Their structure must be homogenous and their ductility must be very high. The material used for the deep drawing of motor car bodies in particular had to meet special requirements concerning its mechanical properties. Yet the metallurgical industries were up to their new task. At present the rolling mills are producing sheet metal of 250 mm. width, and of practically constant thickness over the whole area up to 1.5 mm. The stamping, drawing and allied processes are thus greatly facilitated.

Stamping and Forming Presses.

New deep drawing machines are designed for variable speed to provide the most suitable speed for any particular work.

Toggle lever presses were further developed. The pressure is automatically registered. Damage to the machine itself by excess pressure is prevented by a special clutch.

Eccentric presses were further improved. Small units are fitted with a special clutch which insures a quick pressing operation. Thus the output of the machine is increased, and at the same time their operation made more safe as the high speed prevents the workman from touching the workpiece as soon as it is put in place. Large units now controlled mostly by compressed air and electrically operated valves can be brought to a standstill immediately at any position of the slide. To obtain a highly automatic manufacturing process, even in case of work-pieces requiring a number of operations, special multi-stage machines are in use where the feeding and the transport of the intermediate product is done automatically.

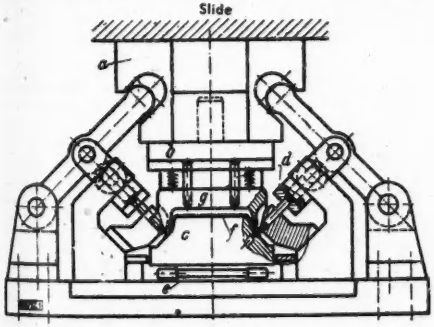


Fig. 1. Multiple tool for punching tap holes. *c* die, *d* punch, *e* handle, *f* shell, *g* shell fastener.

Tools.

The economic design of the tools depends to a great extent on the quantity of the product. It further depends on the way the material is fed into and taken out of the machine, and whether the operations are fully or partially automatic. A multiple tool used for three different operations is shown in Fig. 1. Thereby a much higher accuracy is reached than if the operations were carried out independently, and 67% of the time needed for perforation and 74% of the time for the thread-cutting is saved. Multiple tools are mostly used for small parts such as contacts in electrical switches, etc. The material should be preferably sheets rolled in cold condition which is of sufficiently uniform thickness.

Continuous Production.

Continuous production, if more than one operation is required, is possible through the automatic transport from one machine to the other. This system is very economical, and is used at an increasing rate. By automatic production of the part shown in Fig. 2, 95% of the work time is saved. Fig. 3 shows the eccentric press and the thread pressing machine used in this case.

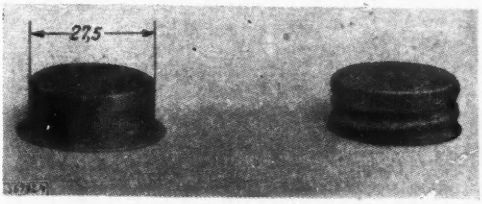


Fig. 2. Cap manufactured on the full automatic machine shown in Fig. 3. Material: Steel VII 23 of of 0.3 mm. thickness.

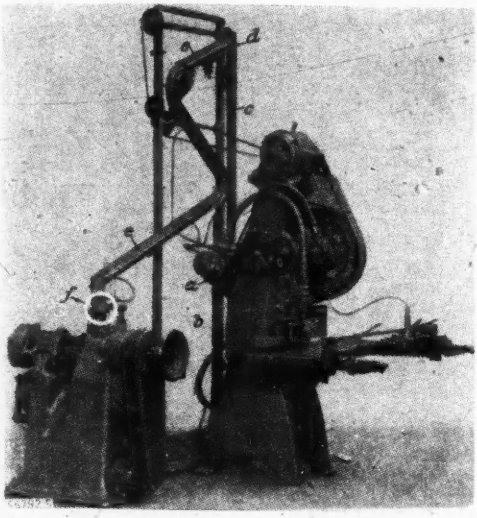


Fig. 3. Stamping and thread pressing machines for manufacture of caps shown in Fig. 2.
a Compressor, *b* Hopper for feeding into elevator *c*, *e* Hopper for feeding into thread pressing machine, *d* Upper end of *e*, *f* Device preventing parts from being fed into the machine in wrong position.

Compressed air supplied by the compressor *a* in Fig. 3 passes through a nozzle and atomizes the lubricant for the deep drawing operation. As soon as the piece is drawn it is pushed by compressed air into the hopper *b*, and further to the elevator *c*. A chain takes it up to point *d* where it is blown by compressed air into the hopper *e*, and fed into the thread pressing machine. A special device prevents any part from being fed into the thread pressing machine in the wrong position.

Cutting.

Sheet metal usually is cut by shearing machines into strips which in turn are cut to the required shape on stamping machines, fitted with various feeding mechanisms like rollers, claws, etc. If sheet iron is cut for use in motors or dynamos, inaccuracies may occur because of the stamping operations being successive. This can be avoided by the method shown in Fig. 4. By the second operation the rotor part is detached and simultaneously the holes *b* for the rivets are perforated and the outer circumference of the stator part is stamped.

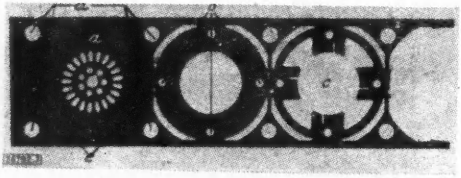


Fig. 4. Sheet metal for motors stamped in consecutive operations. *a* Stamping the rotor sheets, *b* Holes for rivets, *c* Sheets for the poles.
Supply of raw material and transportation is automatic.

Bending and Coining.

Small L-shaped pieces used mostly where two parts are to be joined by spot welding, riveting, etc. are more

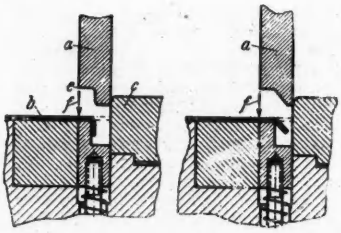


Fig. 5. Stamping L-shaped pieces
a punch
b die
c counter-piece
e cutting edge
f cutting line

economical if stamped than if manufactured in any other way. The tools shown in Fig. 5 are used for this purpose with an eccentric press supplied automatically. The capacity of the machine is about 5,000 pieces per hour, one complete piece corresponding to every stroke of the punch. Fig. 6 shows an aluminium terminal for an electric wire, made on an automatic eccentric press from an aluminium ribbon. The use of an automatic machine producing 120 pieces per minute, and requiring a personnel of only four for the complete production process, resulted in cutting the cost of the part down to a small fraction of its former cost. It is noteworthy that formerly 32 machines and a personnel of 72 were needed to produce the same output.

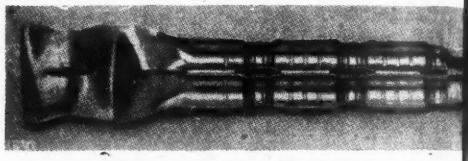


Fig. 6. Terminal for electric wire made on an eccentric press. Material : Aluminium of 0.3 mm. thickness.

There is a new method using small steel cubes as raw material instead of sheet metal used before. Though this method was employed for soft materials like lead, tin, etc., already in the past it is now being used for steel, too. The extent to which time and tools are saved by this process is illustrated by Fig. 7. It is seen that the five operations and the corresponding five sets of tools required for the usual deep drawings are replaced by one operation and one set of tools only.

Multistage Stamping and Forming Presses.

The most perfect of all pressing machines is the automatic multi-stage stamping machine which allows the manufacture of parts requiring several operations on one single machine in such a way that a complete part leaves the machine at every stroke. In addition, the number of intermediate operation does not affect the output. The sheet metal is automatically fed into the machine and the intermediate product automatically transported from stage to stage until it leaves the machine. At every stroke all intermediate operations are performed simultaneously on different pieces. The machine becomes the more economical the more

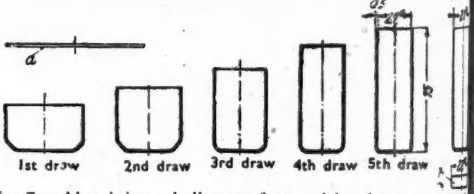


Fig. 7. Aluminium shell manufactured by deep drawing, and, alternatively, by swaging.

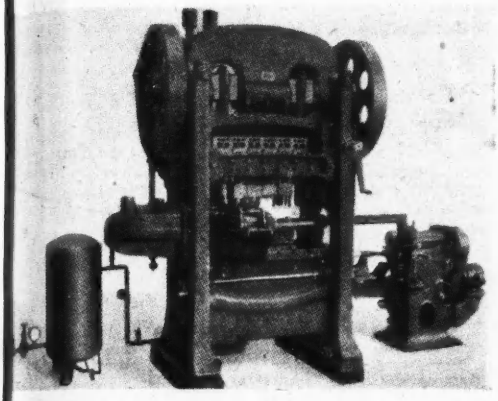


Fig. 8. Multi-stage press with thread pressing machine.

operations are necessary to complete one part. The advantages of this machine are numerous; tools are saved, the material as well as the intermediate products being transported and put into the right position automatically. There is less throw-out, and the dimensional accuracy is much better than on other stamping machines. The annealing sometimes necessary between the stages can be saved, as the number of intermediate operations can be increased without loss of time or machines. Workshop space is saved, as the piece is transported immediately to the next operation and does not need to be stored. For the same reason

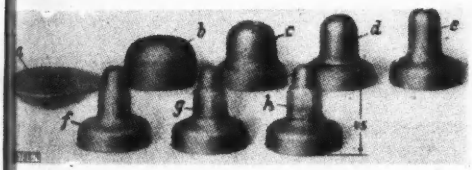


Fig. 9. Lubricator made on a multi-stage forming press. Material: Steel VII 23 of 2 mm. thickness. *a* disc, *b* till *h* 7 operations on the multi-stage press. 85% of working time saved compared with manufacture on single machines.

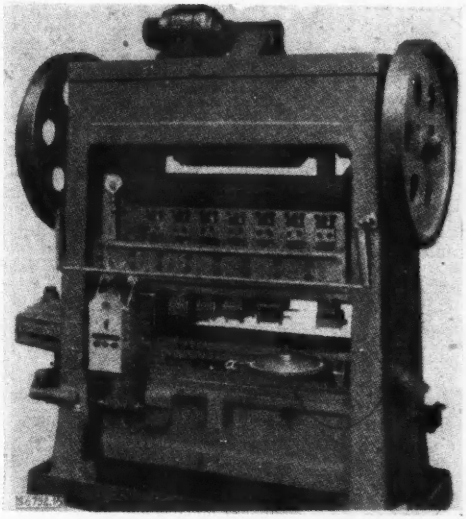


Fig. 10. Multi-stage forming press.

labour for carrying the parts from machine to machine can be dispensed with. Lubrication oil is saved and work preparation, cost calculation and the calculation of wages are facilitated.

Brazing Furnaces with Protective Gas.

Owing to tin shortage, brazing has replaced tin soldering wherever possible. Steel stampings are brazed without soldering paste, borax or the like. A piece of copper wire is fastened to the part, which in turn is put into the conveyor-type electrical brazing furnace. The time of passage usually is 25 minutes. The formation of hammer scale on the workpiece is prevented by the presence of hydrogen in the protective gas of the furnace. On leaving the furnace the parts are completely clean and shining. They are allowed to cool down to 80° to 100° C. in a cooling chamber attached to the furnace. The brazing furnaces can be used also for intermediate annealing for deep drawing, in which case thanks to the absence of hammer scale pickling is not necessary.

CALCULATION FOR RUBBER SPRINGS

By C. W. KOSTEN, Delft. (From *VDI-Zeitschrift*, Vol. 86, Nos. 35/36, September, 1942, pp. 535-538).

Shearing Stresses in Rubber.

As with most solid materials, shearing stresses, τ, are proportional to the angular deformation, tan γ; therefore, the shearing modulus $G = \frac{\tau}{\tan \gamma}$ is a const. for rubber also. This remains true up to $\gamma = 15°$ to $20°$; for higher temperatures, G decreases, e.g., for $\gamma = 45°$, G decreases by 30%.

Tensile and Compressive Stresses in Rubber.

The outstanding feature of rubber, as regards both compression and tension, is its incompressibility. Poisson's ratio is practically $m = 2$ and $G = \frac{E}{3}$, where E = Young's modulus. In other words, the volume remains constant for all deformation.

If a cylinder of height, h_o, and diameter, d_o, is compressed to half of its original height, the dimensions of the resulting cylinder become $\frac{h_o}{2}$ and $d_o\sqrt{2}$. The stiffness—this being the ratio of force/deflection for any spring—of the compressed cylinder is greater than initially. Practically, its stiffness becomes the same as that of a cylinder of original dimensions h_o, $d_o\sqrt{2}$. The well-known apparent hardening of rubber under compression is a consequence of its deformation.

Thus the same coefficient characterizes rubber under compressive and under tensile loads as with Young's modulus E for metals determined from tests within the elastic limit. However, it is more convenient to choose σ_{25}, i.e., the tensile stress, in kg/cm², at which the elongation is 25% of the original length. σ_{25} is simple to measure, being of the same order as practical stresses and also $\sigma_{25} = 0.2E$ in consequence of the constancy of volume.

Influence of the End Surfaces.

The relations described so far are valid within certain limits. For a precision of several per cent, the limits are approximately 90% elongation and 50% compression. Furthermore, in compression rubber is employed in such short length, that there is no uniform distribution of stress across the section. A cylinder is compressed to the form of a barrel, since the rigid bordering surfaces hinder the lateral extension. The effective, i.e., compressible, height h'_o of a cylinder is thus smaller than h_o; practically, the height of the incompressible part is $d_o/8$ and independent of h_o. This is true for cylinders of great height, down to approximately $h_o/d_o = 1/4$.

For other shapes the influence of the rigid ends varies. For strips of width b_o, height h_o and infinite length, the inelastic part of the height is $0.22b_o$ if $h_o > b_o/2$. Such strips may be deformed in only one transversal direction and the theory of elasticity proves that all forces, including spring stiffness, are 4/3 of those of the same rubber with completely free transversal deformation. Tests confirm this coefficient.

Static and Dynamic Spring Characteristics.

Rubber springs are harder under dynamic loads than under static ones. The difference is more aggravated for harder types of rubber (See Fig. 1).

Principles of Design for Rubber Springs.

Between 50% compression and 90% elongation for cylinders and strips, and between -15° and +15° angular deformation, we can apply the following rules:

1. The shearing modulus of elasticity (modulus of rigidity) G = const.
2. The hardening under compression and the stiffening under tension of rubber springs are consequences of the large deformation.
3. For cylinders and strips of infinite length, the efficient height h'_o is the total height reduced by an unelastic part $d_o/8$ for cylinders if $h_o > d_o/4$, by $0.22\ b_o$ for strips if $h_o > b_o/2$.
4. Notwithstanding the difference in the unelastic part of the height, strips of infinite width are 4/3 times stiffer than cylinders.
5. The relations between tensile stresses σ (tensile stress per original cross-section) and strains ϵ, related to the efficient height h'_o, are:

$$\sigma = \frac{\epsilon E}{1+\epsilon} \qquad \text{or} \qquad \epsilon = \frac{\sigma}{E-\sigma}$$

where σ and ϵ are negative in the case of compression. Therefore, $\sigma_{25} = \frac{E}{5}$. Poisson's ratio is $m = 2$, the shearing modulus $G = E/3 = 5/3\ \sigma_{25}$.

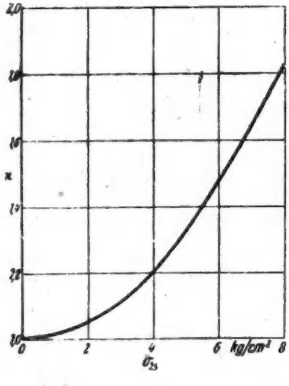


Fig. 1
Ratio κ of the dynamic to the static spring characteristic for rubber of different softness expressed by σ_{25}.

6. The spring constant, i.e., the force necessary to produce a unit deflection for static loads, is:

$$s = \frac{F_o}{h'_o}\,\frac{(E-\sigma)^2}{E} = \frac{F_o}{h'_o}\,\frac{E}{(1+\epsilon)^2}$$

For dynamic loads, the corresponding values are found in Fig. 1.

The above equations are theoretically correct. Practically, there are small deviations and the equations and diagrams which follow are corrected according to tests. The constants of other shapes of springs can be calculated with sufficient accuracy by the aid of these formulae.

Although the relation between σ_{25} and the hardness of rubber are not quite definite, Table I. gives approximate values.

TABLE I. Relation between σ_{25} and some hardness scales.

σ_{25} kg/cm²	Shore-Durometer Hardness (Type A)	Softness according to Din 3503 (Ball of 10 mm. dia.)	Softness according to Pursey and Jones (Ball of ¼ in. dia.)	FOR USE FOR
2	31	150	160	Soft Rubber
4	44	98	107	Soft Rubber
6	55	68	74	Hoses
8	63	53	57	Tyres and Conveyor Belts
10	68	43	47	Tyres and Conveyor Belts

Table II. shows the maximum deformation for which the error on the shearing stress τ (kg/cm²), the tensile stress σ (kg/cm²) and the static spring characteristic s (kg/cm²) is below 5%, resp. below 10%. The values of the dynamic spring characteristics are subject to not more than twice the errors, if $\sigma_{25} > 5$ kg/cm².

TABLE II. Validity of ϵ and γ if the errors τ, σ, and s are not to exceed 5, resp. 10%.

	Error Below 5%	Error Below 10%
τ	$-10° < \gamma < +10°$	$-20° < \gamma < +20\%$
σ	$+90\% > \epsilon > -60\%$	$+100\% > \epsilon > -70\%$
s	$+50\% > \epsilon > -40\%$	$+60\% > \epsilon > -45\%$

The relations are valid for temperatures between 30° C. to 75° C., if σ_{25} > has been determined at the working temperature of the article in question, and if the static values are considered. Generally, stresses are proportional to absolute temperatures. The relationship between the static and dynamic characteristic is subject to the temperature, too, and Fig. 1 holds good from 10° C. to 25° C. approx. For prolonged use above 50° C. special heat-resisting rubbers should be used.

TABLE III. Limits of Compression at which Cylinders and Infinite Strips fail by Buckling. ($-\epsilon_k$) Normal Shape, ($-\epsilon'_k$) Increased Lateral Stability at the ends.

h_o/d_o	$-\epsilon_k$ %	$-\epsilon'_k$ %	h_o/b_o	$-\epsilon_k$ %	$-\epsilon'_k$ %
3	7	25	3	10	23
2	15	42	2	16	38
3/2	23	does not buckle	3/2	21	does not buckle
1	40	does not buckle	1	36	does not buckle
3/4	does not buckle	does not buckle	3/4	does not buckle	does not buckle

For large and permanent pre-loading, e.g., $\epsilon = 25\%$ rubber with a small permanent set must be selected; correctly vulcanized rubber of $\sigma_{25} < 5$ kg/cm² is recommended.

Under large compressions, there is a critical value $-\epsilon_K$ where buckling occurs (Table III.). This value becomes more favourable, if the lateral stability of the ends is improved by auxiliary springs or other means.

Spring Equations.

The following equations are valid in any system of units and contain the mentioned corrections:

For static load: $G = \frac{\tau}{\tan \gamma} = 1.65 \sigma_{25}$

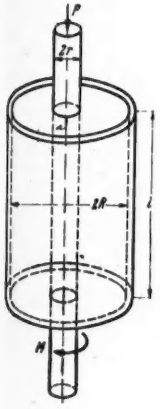


Fig. 2. Rubber under shearing stress between concentric cylinders.

For axial shearing load P between two concentric cylinders (Fig. 2).

$$s = \frac{2\pi l G}{\log_e R/r}$$

the maximum angular deformation on the inner cylinder surface being:

$$\tan \gamma_{max} = \frac{P}{2\pi r l G}$$

For a torsional load with a twisting moment M, the stiffness, i.e., the moment for an angle of twist of 1 radian, is:

$$D = \frac{4\pi l G}{\frac{1}{r^2} - \frac{1}{R^2}} \quad \text{and} \quad \tan \gamma_{max} = \frac{M}{2\pi l r^2 G} \quad \text{is}$$

the maximum angular deformation of the inner cylinder.

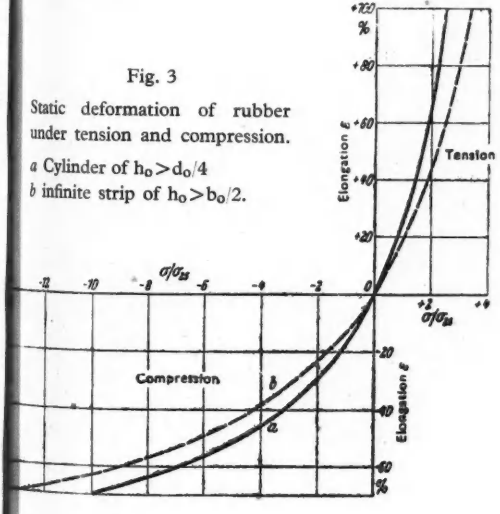


Fig. 3

Static deformation of rubber under tension and compression.

a Cylinder of $h_o > d_o/4$

b infinite strip of $h_o > b_o/2$.

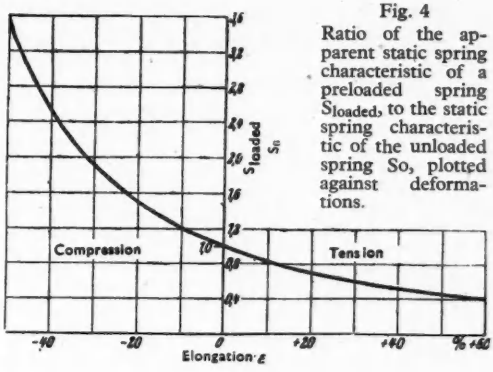


Fig. 4

Ratio of the apparent static spring characteristic of a preloaded spring S_{loaded}, to the static spring characteristic of the unloaded spring So, plotted against deformations.

For tensions and compression:

$$\sigma = \frac{1{,}07\,\epsilon E}{1{,}07 + \epsilon}, \qquad \epsilon = \frac{\sigma}{E - 0{,}93\,\sigma}, \qquad E = 4{,}95\,\sigma_{25},$$

$$s = \frac{F_o}{h'_o}\,\frac{(E - 0{,}93\,\sigma)^2}{E} = \frac{F_o}{h_o'}\,\frac{1{,}14E}{(1{,}07 + \epsilon)^2}$$

$$G = 1{,}65\,\sigma_{25}, \quad m \cdot 2$$

for cylinders: $h'_o = h_o - \frac{d_o}{8}$, if $h_o > \frac{d_o}{4}$

and for infinite strips $h'_o = h_o - 0.22\ b_o$, if $h_o > 0.5\ b_o$.

For these infinite strips, all stresses, including E, σ and s are 4/3 times larger. The static deformation for compression and tension of cylinders and strips is shown in Fig. 3. The initial spring characteristic, i.e., for an unloaded spring is:

$$s_o = \frac{E F_o}{h'_o}$$

The ratio of the apparent static spring constant of a pre-loaded spring, s_{loaded}, to the true static characteristic, s_o, for tension and compression for cylinders and strips is shown in Fig. 4.

For dynamic loads, the spring characteristics are calculated with the aid of Fig. 1. For statically pre-loaded springs the equations referring to static loads are to be used for the static deformation.

Numerical Examples.

1. For a cylinder of $h_o = 2.5$ cm, $d_o = 5$ cm, $F_o = 19.6$ cm², Shore hardness 45, to calculate:

(a) the compression under 50 kg., i.e., at $\sigma = 2.55$ kg/cm². According to Table I. $\sigma_{25} = 4.2$ kg/cm², therefore $4.2 - E = 4.95$. $4.2 = 20.8$ kg/cm². From $\epsilon = \frac{\sigma}{(E - 0{,}93\ \sigma)}$ $\epsilon = -0.11$. From $h'_o - 2.5 - \frac{5}{8} = 1.87$ cm, the compression is $-\epsilon\, h_o = 0.11$. $1.87 = 0.20$ cm.

(b) The force F, corresponding to 0.5 cm of compression.

$$\epsilon = \frac{-0{,}5\ \text{cm}}{1{,}87\ \text{cm}} = 0{,}27. \qquad \text{From}$$

$$\sigma = \frac{1{,}07\,\epsilon E}{(1{,}07 + \epsilon)}, \quad \sigma = -7{,}5\ \text{kg/cm}^2$$

and F is 7.5. $19.6 = 147$ kg.

2. To calculate the natural frequency of the vertical oscillations, and the static deflection of a machine of 1500 kg weight, supported by 4 rubber cylinders of $\sigma_{25} = 4$ kg/cm², $h_o = 5$ cm, $d_o = 10$ cm.

The total cross-section of the rubber is $4F_o = 4 \frac{\pi d_o^2}{4} = 314$ cm² and hence

$$\sigma = \frac{-1500}{314} = -4{,}77 \text{ kg/cm}^2, \quad \epsilon = -0{,}197 \cdot h'_o = -5^{10}/_8 = 3{,}75 \text{ cm}.$$

The static deflection is $-\epsilon h'_o = 0.74$ cm. The nitial spring characteristic $s_o = 4.95\, \sigma_{25} \frac{F_o}{h'_o}$ is for each cylinder $\frac{1560}{3{,}75} = 416$ kg/cm. The natural frequency is calculated from the well-known equation $v = \frac{1}{2\pi} \sqrt{\frac{s}{m}}$ with $s = 754$ and the mass $m = \frac{375}{981}$, as being 7.09 Hz = 425 r.p.m.

Special Shape Rubber Springs.

For shapes not too different from cylinders and strips, an empirical rule indicated by W. C. Keys is sometimes useful. It states that rubber objects with equal ration of free to loaded surface have equal elongation (compression) for equal stress.

Strips of Finite Length.

Because of the greater lateral freedom of a finite strip, deflection is larger than for an infinite one. In compression, there is an increase which is nearly equal to the increase in thickness. The relative increase is assumed to be resisted by a counterpressure, therefore, half the deformation, i.e., $-\frac{\epsilon b_o}{2 l_o}$ is added to the increase, the other half reduces the compression by an equal amount. The finite strip is nearly identical to the infinite one, only the calculated compression $-\epsilon$ should be multiplied by $\left(1 + \frac{b_o}{2 l_o}\right)$. E.g., for $l_o = 10\, b_o$ the correction is only 10%.

Rectangular Blocs.

Approximate calculation is possible either by comparison with strips or with cylinders, and according to the form of the blocks, one or other method can be selected.

When comparing with a strip, the formulae for strips of finite length are used. When comparing with a cylinder, the average between 1/8 of the width and 1/8 of the length is to be taken as being the unelastic portion of the height. For very short blocks, an amount somewhat larger might be considered, in consequence of the great diagonal extension. As this is only a correction, great accuracy is not required.

Cylindric Rubber Springs of General Cross-section.

Numeric characteristics may be determined by the following direct method, if more exact values are not known :

4 test specimens from any elastic rubber composition are manufactured with $\sigma_{25} = 3$ kg/cm² approx., 3 of which are cylinders of the required cross-section, but of various heights ; the fourth is rod-like normal test-specimen. The three cylindrical specimens are tested under compression. Then we may write :

$$h'_o = h_o - c_1 b_o \quad \text{and} \quad E = c_2 \sigma_{25}$$

where b_o is an arbitrarily chosen dimension in width, e.g., the greatest or the smallest width. σ_{25} is determined by testing the fourth specimen. c_1 is then chosen in such a manner as to make the three graphs $\sigma = f(\epsilon)$ of the cylinders coincide as far as possible. From each pair of values σ, ϵ of this graph c_2 can be calculated with the aid of the above mentioned relation between σ, ϵ and E. The two equations thus become true for all cylinders with the same cross-section, as the three specimens, but with any heights and manufactured from any type of rubber composition. Of course, for each type of rubber the corresponding σ_{25} must be introduced into the formulae. For important applications, a check test is recommended, e.g., with different rubber and different height. For small h_o the equations are not true ; the limit lays between $h_o = 1/4$ of the smallest thickness for objects of small width and $h_o = 1/2$ the smallest thickness for objects of distinct extension in width.

EXTENSOMETER MEASUREMENTS on the BACK AXLE OF A LORRY

By Dr. Ing. Habil. Ernst Lehr and Ing. Richard Schulz. (From *ATZ Automobiltechnische Zeitschrift* Vol. 45, No. 17, 10th September, 1942, pp. 461-470).

The objects of the experiments performed at the "Forschungsanstalt der M.A.N., Werk Nuernberg" was to determine the following quantities :—

(*a*) The bending moment M_{bw} acting in the horizontal plane passing through the centre line of the axle.

(*b*) The bending moment M_{bs} acting in the vertical plane passing through the centre line of the axle.

(*c*) The torque M_d acting in the axle.

Fig. 1 shows the back axle with mounted extensometers, the measuring length of each of these being 20 mm. It can be seen that both sections, at which the measurements are being taken, have a uniform stress distribution. Fig. 2 shows the distribution of the six extensometers round the I-section of the axle. The extensometers are mounted on tapered pins, which are brazed to the axle by means of a gauge.

With a bending moment in the horizontal plane only, the extensometers 2 and 5 must not give any reading, as they are in the neutral layer. The extensometer readings 3 and 4, on the other hand, must be numerically equal but of opposite sign, to the extensometer readings 1 and 6. Similarly, with a bending moment acting in the vertical plane only, the extensometer readings 1 and

Fig. 1. *a* Instruments for measuring bending moments *b* Instruments for measuring torque.

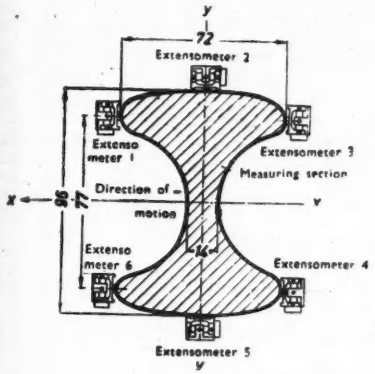


Fig. 2

3 must be numerically equal and of opposite sign to readings 4 and 6.

First each instrument was separately calibrated; the relation was established between the movement of the light-spot on the oscillograph screen and the corresponding change in measuring length. All calibration curves were straight lines.

A check was obtained by mounting the axle in a testing machine, and applying bending moments of known value in horizontal and vertical planes respectively. Thus certain corrections were obtained which are due to the following facts. As the extensometers are mounted on tapered pins they measure the change of length of an "imaginary layer," which roughly corresponds to the centre line of the extensometers. Furthermore, the stress distribution at the measuring section of the axle is not perfectly linear, which is assumed in the calculations.

Section II. is used for the measurement of the torque M_d. The extensometers measure the relative twist of Sections II. and III., which are 82 mm. apart.

Plates are brazed at both sides of the axle at Sections II. and III. (Fig. 3), the overlapping parts of which carry the tapered pins for the extensometers. A relative angular displacement of Sections II. and III. results in a change in measuring length indicated by the extensometer. Experiments show that the torque is influenced only to a very slight extent by an additional bending moment, and that this effect can be neglected.

The calibration of the extensometers was done in a torsion testing machine. Curves of oscillograph reading plotted against torque are shown in Fig. 4.

The Extensometer.

The circuit diagram of the extensometer is shown in Fig. 5. It is most important that the static calibration is also valid for dynamic measurements of vibrations of a maximum frequency of 300 cycles per second.

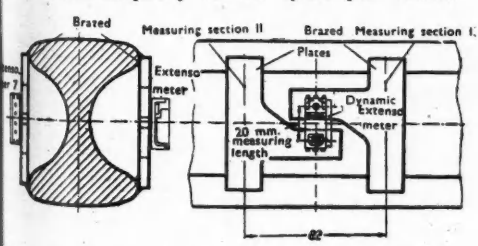


Fig. 3. Arrangement of the extensometers for torque measurements.

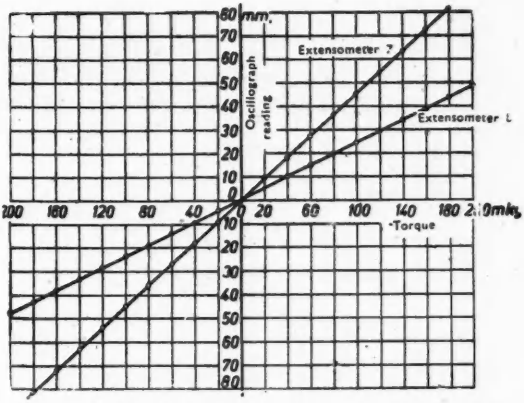


Fig. 4. Calibration curves for the extensometers used for torque measurements.

Furthermore, it must be possible to recalibrate the instrument before and after each experiment. The above requirements can be fulfilled only if the extensometers are supplied with a frequency which is at least 20 times the frequency of the vibrations to be measured. In this case a frequency of 10,000 cycles per second was used. It is desirable that the current and the frequency remain constant during the test, and that the extensometers are not influenced in any way by the circuit.

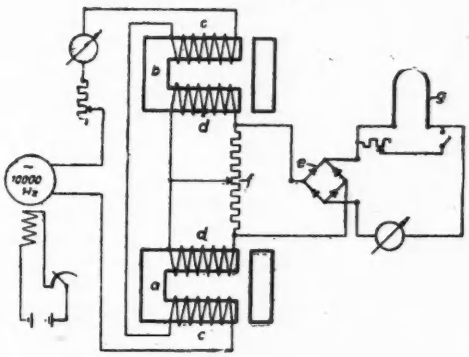


Fig. 5

a Extensometer magnet
b Adjustable comparison magnet
c Primary winding
d Secondary winding
e Copper oxide rectifier
f Adjustable resistance
g Oscillograph coil

The construction of the generator used can be seen from Fig. 6. Four completely independent generators are contained in one casing; thus four measuring circuits can be supplied, without one influencing the other in the least. The rotor consists of thin, insulated plates; 100 evolute teeth are cut into its circumference with a high degree of accuracy. In contrast to ordinary teeth, they are only cut to the pitch circle, so that the teeth and the gaps between the teeth are of the same width. The shaft is running in plain, ring lubricated bearings, with a very small clearance. The rotor is

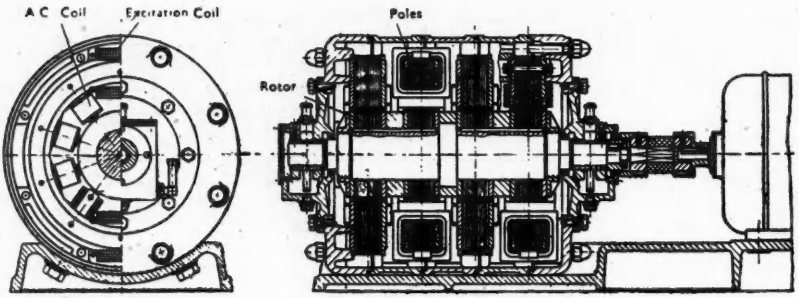


Fig. 6. Construction of the generator for four measuring circuits (10,000 cycles per sec.).

machined to an accuracy of about $\frac{1}{1{,}000}$ mm., concentric with the journals, and is most carefully balanced. It is driven through a rubber coupling by a D.C. shunt motor (n=6,000 r.p.m.), the speed of which can be regulated through a fine adjustment and is measured by a tachometer. An accumulator generally supplies the current for the motor.

The stator is also built up of thin lamination plates, and has eight poles. Into each pole face four teeth are cut. The teeth of the outside poles are displaced relatively to those of the inside poles by half a division. Thus it is possible to maintain a constant flux in the lamination which carry the field coils, when the armature is rotating, thus preventing induction effects in the excitation windings. In order to neutralize any induction currents caused by any dissymmetries, short-circuited copper windings are mounted next to the field coils. An alternating current of 10,000 cycles per second is induced in the A.C. coils wound on the poles, the relative motion of the teeth on the rotor and the poles resulting in an alternating flux.

Owing to slight magnetic dissymmetries of the rotor a disturbing frequency coinciding with the speed of the rotor is superimposed. This disturbance was reduced to a minimum by keeping the air gap between rotor and pole faces as uniform as possible and finally by connecting the A.C. coils in series in a certain order.

Each measuring circuit (Fig. 5) consists in principle of an extensometer-magnet *a* and a comparison-magnet *b*. Both magnets are built up of thin sheets of a special alloy and are perfectly identical; they consist of a horse-shoe electro-magnet with two windings, and a " keeper " placed in front of the poles but not touching them. The air-gap of the extensometer magnet depends on the extension of the measuring length, while the air-gap of the comparison-magnet can be adjusted to an accuracy of $\frac{1}{10{,}000}$ mm. by means of a differential micrometer screw. The extensometer-magnet is fixed in the base of the housing, which is mounted on a tapered pin at one end of the measuring length, while the " keeper " is fixed to the lid of the extensometer which is mounted on another tapered pin at the other end of the measuring length.

The primary windings of the extensometer and comparison magnets are put in series, and are connected through an adjustable resistance to a generator of 10,000 cycles per second. The currents in the primary windings of both magnets are therefore at any instant equal and in phase. The secondary windings oppose each other. The magnets are adjusted, so that they have exactly the same inductivity. If, therefore, the two air-gaps are equal, the induced voltages in the secondary windings neutralize each other, and there is no current in the secondary circuit. During the measurements the comparison-magnet is adjusted so that the voltage in its secondary winding is always larger than that in the secondary winding of the extensometer magnet. Then, with a change in the air-gap of the extensometer-magnet, an A.C. of modulated amplitude is produced in the measuring circuit, the envelope of which represents exactly the extension of the measuring length, and the frequency of which is 10,000 cycles per second.

The secondary current can be recorded on the screen of an oscillograph. This is shown in Figs. 7 and 8, for a case, where the extensometer is fixed to the connecting rod of a two-stroke Diesel engine. The measuring method can only be considered simple if the instantaneous oscillograph readings are proportional to the extension of the measuring length. This is the case in the method used. The secondary circuit contains a copper-oxide rectifier which cuts off the part of the diagram below the abscissa (Fig. 7), resulting in the diagram shown in Fig. 8. The coil of the oscillograph is directly connected to the D.C. side of the rectifier. It has a resistance of 4 ohms, and a natural frequency of about 2 cycles per second. The maximum current that can be temporarily passed through is 8 mA. The deflection of the light spot is, at any instance, proportional to the ordinate of the envelope of the oscillogram. The inertia of the measuring coil is so high that it cannot follow the frequency of 10,000 cycles per second. Thus the oscillogram gives a true picture of the extension of the measuring length, without the occurence of harmonics. If, therefore, the extensions follow a sine law, the oscillograph will also record pure sinusoidal vibrations. A circuit diagram is purposely chosen which makes complications such as selectors, etc., superfluous; similarly, the use of an amplifier is intentionally avoided.

(*To be continued*)

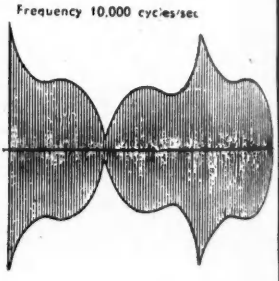


Fig. 7 (upper figure) Oscillogram of the A.C. in the secondary circuit before rectification.

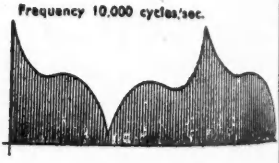


Fig. 8 Oscillogram of the current in the oscillograph-coil circuit after rectification.

TECHNICAL NEWS

Announcements in this section include News relating to British Firms, and on Equipment produced by British Manufacturers.

Available literature may be secured by addressing a request to the advertising department of "The Engineers' Digest," or by writing direct to the manufacturer and mentioning "The Engineers' Digest" as a source.

- ✦ NEW EQUIPMENT
- ✦ BOOKS AND CATALOGUES
- ✦ BUSINESS CHANGES
- ✦ PERSONAL
- ✦ NOTES

NEW EQUIPMENT

SALVAGE OF POROUS CASTINGS.

WHERE castings are intended for use at high pressures and temperatures it is essential that they should not be porous, therefore, interest attaches to a process in operation at the works of Commercial Structures Ltd., Staffa Road, Leyton, London, E.10, in collaboration with Bakelite Ltd., which is capable of rendering serviceable a large percentage of porous castings.

The process is simple and consists in subjecting the castings to a treatment with Bakelite Sealing Solution under moderate pressure in order to ensure that all pores are sealed with Bakelite Solution.

The casting to be treated should be reasonably clean and free from patches of moulding sand. It is blanked off at the various openings so as to form a closed vessel, provision however is made for the reception of the connection to the high pressure pumping system.

The Bakelite Sealing Solution is then pumped into the casting interior under a pressure of 50 lbs. to 600 lbs. per square inch, depending on the strength and future duty of the casting. The object of this pressure is to force the Bakelite fluid well into all pores and interstices. The pressure is maintained on the fluid in the casting until the fluid has permeated and filled up the pores. If the casting is slightly porous sweating will occur on the external surfaces, whilst if badly porous, the fluid may come through in form of fine spray.

This impregnation process is carried out at normal atmospheric temperatures and in order to fix and stabilise it (rendering it almost infusible and non-susceptible to most forms of attack), it is subjected to a controlled heat treatment in an oven for a definite time at atmospheric pressure.

The temperature is kept fairly constant and below 100° C. until the solvents have evaporated from the fluid when the temperature is raised for another definite period of time and finally raised to the finishing temperature value for a definite period. The heat treatment lasts for approximately 3 hours. Should the casting have been so porous that after this treatment it still remains porous, it may be subjected to a second and similar treatment.

After treatment, test pressures may be applied and maintained up to 8000 lbs. per square inch, upon castings which are strong enough. The treatment is applicable equally satisfactorily to ferrous and non-ferrous metals, including the light metal alloys.

This method of salvage should be of particular interest to firms who specialise in high pressure and temperature apparatus, or where the nature of the medium flowing in the systems causes external deposit of dirt or salts due entirely to weeping or seepage through porous castings, valves and pipe lines. Commercial Structures Ltd. will be pleased to demonstrate the process to interested parties.

NEW METHOD OF ETCHING ON METALS.

A NEW, cheap and simple method of etching trade marks, part numbers, patent numbers, or designs on to the surface of metals has been developed recently. The method is rapid and simple to operate and it can be applied to brass, nickel, indeed, to any metal. It enables a number of small articles to be etched in the same time as taken for one article. A whole sentence can be etched as rapidly as one word. It has no limitations in the complexity of the design which can be transferred, provided only that a stencil can be cut. Awkward shapes lend themselves particularly to etching by this method. It is extremely simple to operate, no tools are required, and beyond the cost of the stencils and etching solutions the running costs are negligible.

The process is electrolytic and makes use of a standard waxed paper stencil, such as is used on a duplicating machine, on which are typed or printed the required words or designs. The stencil is placed between the metal article, which forms the anode, and an absorbent pad containing the etching fluid, which is connected to the cathode of a 15 volt D.C. circuit.

The apparatus consists of a unit comprising transformer, rectifier and output controller, which gives a potential of 15 volts D.C. from the 200/230 volts A.C. supply.

The current is turned on for a period varying from 5 seconds for a small design to 10 seconds for a larger one, or even 30 seconds where, say, 20 metal objects are being etched at once. The current varies from 2 amps. up to approximately 10 amps. for a large number of articles. It is important in the latter case that sufficient mechanical pressure is maintained to ensure good contact with each specimen. It is not necessary for the surface of the metal article to be free from grease before engraving since greasy surfaces etch quite well. When etching stainless or corrosion resisting metals, each cut in the stencil is good for at least 15 etchings, the life being limited by the tendency of the stencil to become burned, and the etching to become blurred. The life of the stencil is reduced to about 10 engravings with less corrosion resisting metal such as mild steel, as the dielectric properties then become impaired.

The normal depth of the engraving is about .0005" and an important feature of the process is that in no way is the structure of the adjacent metal altered, nor is the surface of the metal embossed, but remains perfectly flat. The etching appears as a silvery colour on mild steel and is more brilliant on stainless metals. It can be filled afterwards, if desired.

Round or curved articles can be rolled over the stencil whilst in contact with the top block, or alternatively, awkwardly shaped or large articles can be etched by fitting the waxed stencil to the curved face of a hand blotting pad and making the necessary electrical connections to the metal body of the hand blotter and the article.

The method is particularly useful for marking toolroom products.

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The running cost is very small, as a large number of markings can be typed on one stencil. The apparatus is obtainable from Messrs. Griffin & Tatlock Ltd., Kemble Street, Kingsway, London, W.C.2.

MEASURING TIN COATINGS.

THE full range of methods available for assessing the thickness of a tin coating is given in the Tin Research Institute's Publication, No. 115, which may be obtained free of charge from the Tin Research Institute, Fraser Road, Greenford, Middlesex.

The methods described come under the following general headings:

(a) Weighing the component (or test piece) before and after stripping the tin in a chemical solution.

(b) Completely dissolving the specimen and determining the tin by analysis.

(c) Measuring the time required to dissolve the coating.

The publication also contains useful conversion tables showing the weight of tin on various units of area, corresponding to different thicknesses of coating.

TESTING THE QUALITY OF TIN COATINGS.

THE new electro-tinplate, which uses only one third as much tin as normal tinplate, has so thin a coating on it that the established methods of testing its continuity are inapplicable. The Tin Research Institute's Publication, No. 116 (reprinted from the Journal of the Society of Chemical Industry) describes new tests devised by Dr. R. Kerr. One of the new tests is particularly interesting, as it provides a simple numerical value of the amount of iron exposed to attack over a considerable area, without making a laborious count of rust spots and without the elaborate apparatus required for the hydrogen test.

In the first of the new methods, which is suitable either for thick or thin tin coatings, an oxide film is formed on the surface of the tin before applying the hot water test. This pre-filming treatment greatly accelerates the test, so that clearly defined rust spots are developed in 40 minutes.

The second method is a modification of the ferricyanide paper test. A paper of suitable texture is soaked in a ferricyanide solution containing a textile penetrating agent, and is then pressed on to the specimen with a roller squeegee. After 10 minutes the pores in the coating appear as blue spots on the paper.

The third test determines the quantity of iron dissolved from pores in the tin coating when the specimen is immersed for 15 minutes in an acid thiocyanate solution. This method gives a measure of the quality of the tin coating, and is applicable to any type of tinplate.

Copies of the publication, No. 116, may be obtained free of charge from the Tin Research Institute, Fraser Road, Greenford, Middlesex.

BUSINESS CHANGES

Rubery Owen Messier Ltd., of Warrington, Lancs, Manufacturers of undercarriages and other aircraft equipment, have announced to the trade that they will henceforth carry on business in the name of Messier Aircraft Equipment Ltd. The Board of Directors and Management remain unchanged.

CATALOGUES

Ilford Ltd., Ilford, London, have issued a 16-page booklet dealing with the industrial applications of X-rays and Gamma Rays. The booklet includes details on films, papers, intensifying screens and chemicals manufactured by Messrs. Ilford Ltd.

PERSONAL

Mr. A. E. Crabtree, Joint Managing Director of Messrs. R. W. Crabtree & Sons of Leeds, has died recently.

Mr. Greville A. Maginess, Chairman of the A.B.M.T.M. Ltd., Chairman of the Churchill Machine Tool Co. Ltd., Chairman of Roneo Ltd., a Director of Tube Investments Ltd., has been appointed President of the Engineering and Allied Employers' National Federation.

Sir George Nelson has been elected President of the Federation of British Industries.

Dr. A. Parker, M.Sc., F.I.C., M.I.Chem.E., has been appointed Director of Fuel Research in the D.S.I.R.

Mr. R. C. Rattray has been appointed Assistant Chief Engineer to the L.N.E.R.

Professor Dr. Aurel Stodola, an outstanding personality of mechanical science, Professor of the Polytechnikum at Zurich, has died on December 25, 1942. Professor Stodola who was of Czechoslovakian origin, was awarded the James Watt International Medal by the Institution of Mechanical Engineers in January, 1941, on which occasion Dr. H. L. Guy, F.R.S., now Secretary of the Institution of Mechanical Engineers, has delivered an appreciation of his scientific work especially in connection with the development of the Steam Turbine.

Mr. S. C. Waddington, M.I.Mech.E., has been appointed Works Manager to Messrs. Ashmore, Benson, Pease & Co. Ltd.

Mr. W. B. Wragge, B.Sc.Techn., has been appointed a Director to Messrs. Exors. of James Mills Ltd.

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